STUDIES ON NITROGEN AND SULPHUR NUTRITION OF SORGHUM VARIETIES FOR FORAGE YIELD AND QUALITY UNDER RAINFED CONDITIONS

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CERTIFICATE

This is to certify that the thesis entitled "**Studies on nitrogen and sulphur nutrition of sorghum varieties for forage yield and quality under rainfed conditions**" presented to Bundelkhand University, Jhansi (UP) for the award of the **Degree of Doctor of Philosophy in Agricultural Sciences (Agronomy)** is a record of bona fide research work carried out by **Shri Vishram Singh Yadav**, Additional District Magistrate (F&R), Jhansi at Indian Grassland and Fodder Research Institute, Jhansi under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form.

It is also certified that Shri Yadav has put in the attendance required under the University's statutes during the course of present investigation for the last three years.

Dated: 19.9.91

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INTRODUCTION

I N T R O D U C T I O N

In India the crop and livestock enterprises constitute two functional components of mixed farming system in determining the agricultural economy and maintaining ecological balance. The forages form the mainstay of our livestock industry to minimise the competition between human beings and animals for needed nutrients owing to land and input constraints. The Policy Advisory Group on Grazing and Livestock Management of Government of India (1990) has projected the livestock population to 494 million for 2000 A.D. The requirement of green fodder, dry matter and concentrates for the country's livestock population at their optimum plane of nutrition has been put at 837, 529 and 95 million tonnes respectively (Singh, 1990). The National Commission on Agriculture (1976) has, however, indicated the corresponding deficit of 64, 16 and 80 per cent of the requirement and that too by feeding poor quality roughages. On the other hand, only 8.3 million hectares (4.4%) of the country's cropped area is under fodder crops and there is no scope of allocating irrigated agricultural lands exclusively for this purpose because of existing pressure on such lands for food and cash crops. Alternatively the feed and fodder resources have to be developed on vast dryland areas subject to frequent drought which otherwise remain risky for economic grain production.

Sorghum (Sorghum bicolor (L.) Moench) is an important food and fodder crop adapted to dryland conditions, and is grown on an area of 16 million hectares in the country. In northern India forage sorghum occupies more than 80 per cent of the total acreage under fodder crops during summer and rainy seasons.

Sorghum grown for fodder is popularly known as chari justifying its paramount importance in animal nutrition. It has been recognised as an ideal forage crop due to its quick growth, high yielding ability, high dry matter content, better quality and its suitability for various forms of utilization like soilage, silage and kadbi (hay). At flowering stage the green forage on an average contains 5-9 per cent crude protein, 30-32 per cent fibre, 48-50 per cent neutral detergent fibre, 50-60 per cent total digestible nutrients, 2-5 per cent digestible crude protein and 50-60 per cent dry matter digestibility. The average voluntary dry matter intake varies from 1.5-3.0 kg/ 100 kg body weight (Lodhi and Grewal, 1988). Thus sorghum provides energy rich green, palatable and nutritious forage over extended period of time.

The development of high yielding, drought resistant, fertilizer responsive and nutritionally superior varieties has been the major concern of plant breeding programme in forage sorghum. As a result of concerted efforts several superior strains have been evolved and many more are in the pipelines at various stages of evaluation. Among recent releases, PC-6, HD-2

and HC-136 have been found very promising both for irrigated and unirrigated areas of the entire country. These strains, however, differ considerably in their adaptability to dryland environment, productivity potential, nutrient requirement, fertilizer use efficiency and herbage quality.

In dryland areas, however, the soil fertility may be as limiting as moisture because dryland soils are not only thirsty but hungry as well. Though nitrogen and sulphur have been nutritionally labelled as primary and secondary elements respectively but with the intensificaton of agriculture and the ever increasing demand for nutrients made by crops on the soil and fertilizer system, the traditional boundaries are becoming narrower. It is in this context that N and S nutrition of forage sorghum merits due attention as these nutrients resemble with each other in their function in plant metabolism.

Sorghum being graminaceous species requires heavy dose of fertilizer nitrogen for producing succulent high quality herbage. It is an efficient nitrogen user among cereals and responds to as high as 280 kg N/ha (Gill _et. al_. 1967). Nitrogen is the key element in crop growth and is the most limiting nutrient in Indian soils. The paramount importance of nitrogen for luxuriant vegetative growth, early bulking of crop and quick regeneration, following cutting/defoliation has been widely accepted. The

major portion of the nitrogen taken up by the plants is used in synthesizing protein. However, about 10-30 per cent of the total N in graminaceous species occurs in non-protein nitrogen (NPN) form. It has been empirically established that for every 15 parts of N in protein there is 1 part of S which implies that N:S ratio is fixed within a narrow range of 15:1. Therefore, a lack of S would reduce the amount of protein synthesized even if there were plenty of N available to the plants. Sulphur deficiencies are most commonly encountered in crops requiring large quantities of nitrogen as plants need 1/10th to 1/15th as much sulphur as nitrogen. The critical limit of available S in soil has been reported to be 10 ppm for crop responses (Tiwari et. al. 1980). Soil treatment with sulphur improves the nutritional value of the forages probably by balancing the amino-acids and other complex compounds of synthetic origin within the plants (Chopra and Kanwar, 1966).

Sulphur relation with nitrogen is important both in plant and animal nutrition. In plant-animal system both N and S apart from increasing crude protein content of fodders, play an important role in determining the optimum N:S ratio. It is claimed that closer the N:S ratio in the plant, the better is the plant growth. A deficiency of S causes accumulaton of nitrates, amides and carbohydrates. The optimum N:S ratio in forages for ruminants is considered to be 10:1 to 15:1 (Kanwar, 1976). When they

contain N:S ratio wider than this, ruminant fed on them adjust by wasting nitrogen resulting in decreased efficiency of feed protein utilization.

Sorghum crop also develops hydrocyanic acid (HCN) to the critical limit of toxicity for animals ($>$250 ppm) under drought conditions due to increased soil moisture stress. Sulphur is reported to reduce the HCN content in plants. Moreover, the importance of S has not been fully recognised and only in a few cases S is included in fertilizer recommendations. Of all the studies on S fertilization only 7 per cent are devoted to forages. The problem is likely to be further aggravated with recent trend in the use of high analysis fertilizers free from sulphur.

The research information on combined effect of N and S in realizing potential yield, modifying chemical composition and regulating HCN content in different varieties of forage sorghum is rather meagre. Since fertilizer management strategies in forage crops aim at increasing herbage yield per unit area per unit time alongwith improvement in quality traits to take care of two biological system viz., 'Soil-plant' and 'Plant-animal', therefore, the present investigation entitled, "Studies on nitrogen and sulphur nutrition of sorghum varieties for forage yield and quality under rainfed conditions" was undertaken at Indian Grassland and Fodder Research Institute, Jhansi (UP) with the following objectives:

(1) To study the growth parameters and production potential of important varieties of forage sorghum at different levels of nitrogen and sulphur in Bundelkhand region.

(2) To find out the optimum levels of nitrogen and sulphur for sorghum varieties under rainfed conditions.

(3) To examine the influence of N and S nutrition on chemical composition and quality traits at different growth stages of sorghum varieties under rainfed environment experiencing periodic moisture stress.

(4) To study the interactive effects of N and S nutrition on degree of plant water stress and in turn on quality parameters specially HCN accumulation in different sorghum varieties under dryland conditions.

(5) To identify ideal combination of variety, nitrogen and sulphur for greater herbage yield and nutrient out turn of forage sorghum under rainfed conditons.

REVIEW OF LITERATURE

R E V I E W   O F   L I T E R A T U R E

This chapter is an attempt to review the available literature on the response of sorghum varieties to nitrogen and sulphur nutrition in relation to growth characters, forage yield and quality traits. However, relevant scientific informations on other forage crops have also been included wherever deemed essential to cover the subject of investigation in comprehensive manner.

Production potential of forage sorghum varieties

The development of high yielding nutritious varieties responsive to different management levels, efficient in input use and ability to fit in the existing cropping system has been the major research thrust in forage sorghum (Paroda and Lodhi, 1982). So far large number of sorghum varieties suited to various agroclimatic conditions have been bred and released. The characteristic features of most of the varieties including PC-6 and HC-136 have been documented well in recent publications of lodhi and Grewal (1988) and Lodhi and Chowdhury (1988). Reconstruction of improved sorghum varieties is being pursued at many locations in India through All India Coordinated Research Project on Forage Crops with its Head-quarters at Indian Grassland and Fodder Research Institute, Jhansi (UP). In varietal evaluation, PC-6 and HC-136 have been identified for whole of the country and their

production potential varies from 400-500 q/ha in terms of green forage (Hazra, 1989). HD-2, however, has the potential of producing 500-550 q/ha green matter with 140-160 q/ha dry matter (IGFRI, 1990).

In trial on sorghum cultivars under different nitrogen levels, Shinde et. al. (1987) found that cv Haryana Chari S-136, Pusa Chari-6 and M.P. Chari gave average fresh fodder yields of 88.91, 70.00 and 59.79 t/ha respectively in 3 cuts. Similarly, Thakre et. al. (1987) reported that out of the 12 sorghum varieties tested, the cultivars of PC series such as PC-28 produced the highest total fresh fodder of 58.33 t/ha and PC-21 gave the maximum dry matter yield of 13.84 t/ha in 3 cuts.

Rammah and Ali (1980) observed significant differences among cultivars for most of the forage yield components. Hybrids exhibited better growth characters and responded more to high rates of nitrogen than other cultivars. Similarly Joshi and Upadhyay (1977) also observed that sorghum hybrid cv. CSH-4 gave significantly higher fodder and grain yield, plant height, leaf area and total dry maatter than cv. CSH -1 and S-302. Under irrigated conditions, hybrids DSH-1 and CSH-5 gave the highest yields of 8.60 and 8.41 t/ha, respectively compared with 5.33 to 6.64 t/ha for other cultivars (Pavate et. al., 1988).

From a three years study at Dharwad in Karnataka (Jayanna, et. al., 1986) reported that the green fodder yields of Pioneer hybrid-988 (66.98 t/ha) and J.Set 3 (66.35 t/ha) were more than SB-1079 (59.33 t/ha) when only one cut (main crop) was taken. However, because of better ratooning ability the total yield from two cuttings of Pioneer hybrid-988 was found to be more than remaining two entries. There was significant effect of fertilizer levels on green fodder yield. Higher level of fertilizer (150-75-50 kg NPK/ha) increased the yield of green fodder (83.68 t/ha) significantly over low fertilizer level (75-37.5-25 kg NPK/ha). In Gujarat, hybrid AS-15 gave the yields of 14.94 t DM and 0.90 t CP, compared with 7.6-10.6 and 0.49-0.65 t respectively for other genotypes (Raj and Patel, 1988).

Response of forage sorghum to nitrogen nutrition

Nitrogen nutrition of forage sorghum received greater attention realising its paramount importance both for increasing yield and improving quality particularly the level of protein. The response to nitrogen has been variable depending upon soil status, moisture availability and varietal characteristics. Comprehensive studies at Indian Grassland and Fodder Research Institute, Jhansi indicated that the response of single cut sorghum to nitrogen ranged from 60-90 kg/ha for green and dry matter yields (Menhi Lal and Tripathi, 1987). Nitrogen exercises

favourable effects on growth attributes (plant height and number of leaves), palatability characteristics (leaf:stem ratio), quality parameters (protein and fat) and herbage yield of sorghum (Bajwa et. al., 1983; El-Kassaby, 1985). Gujar et. al. (1985) observed that fresh fodder yield and dry matter content of 3 sorghum varieties increased with increasing rates of nitrogen from 0 to 100 kg/ha. There was, however, no significant difference between 80 and 100 kg for yield and between 70 and 80 kg for dry matter content. Crude protein content also increased with nitrogen rate. Desai and Deore (1980) working at Rahuri reported significant increase in green fodder yield of sorghum with 120 kg N/ha (300 q/ha). The interaction of varieties with nitrogen was also significant.

In another study nitrogen application upto 150 kg/ha enhanced crude protein and crude fibre contents of different sorghum varieties apart from increasing the dry matter yield linearly (Medina et. al., 1984). Nitrogen recovery by sorghum has, however, been reported to be low under severe drought situation (Silveira et. al., 1984). Consequently this leads to the variation in nutrient uptake, chemical composition of plants and finally the herbage quality.

Studies on nitrogen nutrition of multicut sorghum varieties in Maharashtra indicated that the forage yields with 160 and 200 kg N/ha were similar and significantly

higher than with 0 or 120 kg N/ha. Digestible crude protein content increased from 3.98% with no N to 7.10% with 200 kg N/ha. Crude fibre content decreased from 24.23% to 20.82% with increase in N rate (Shinde et. al., 1987). Raut and Ali (1987) observed that application of 30-60 kg N and 30 kg P_2O_5/ha to rainfed sorghum grown on vertisol increased the plant height, leaf area, fresh fodder and DM yields. Average green and dry matter yields of M.P. Chari in two cut system increased with application of FYM and with increasing N rates, yield increases were generally greater with basal than split N application. Crude protein content and yield were higher for the 1st cut and increased with increasing N rate upto 100 kg/ha and with manure application (Gill et. al., 1988).

Pereira et. al. (1989) studied the effect of 0, 45, 90 and 135 kg N/ha on forage sorghum, one-third applied at sowing and the remainder top-dressed 64 days after sowing. Forage was harvested at the floury grain stage. Average DM yield increased from 6.32 t/ha without N to 7.49 t/ha with 135 kg N/ha. Crude protein content was significantly affected by N rate.

In case of fodder maize, application of 40, 80 and 120 kg N/ha increased fresh fodder yields. There was non-significant difference between 80 and 120 kg N/ha. Harvesting at the tasseling, silk and milk-ripe stages gave similar yields (Sawant and Khanvilkar, 1987). The

investigation by Khandaker and Islam (1988) showed that the green fodder yield of maize increased with increasing N rates from 25.62 t/ha without N to 41.03 t with 63 kg N, and increased to a maximum of 35.13 t when harvested after 8 weeks. DM yield was little affected by rate of N but increased as harvesting was delayed until 9 weeks. Fodder CP content was highest (88.3 g/kg) when 63 kg N/ha was applied and declined as harvesting was delayed.

Raja et. al. (1988) observed that the green fodder yield (406.6 q/ha) of sweet sudan grass with 100 kg N/ha was at par with that of 80 kg N/ha but significantly superior to 60 kg N/ha. The experimental findings of Singh et. al. (1989), however, indicated that as the nitrogen doses increased from 0 to 90 kg/ha both the green forage and dry matter yields also increased significantly. Maximum green and dry matter yields were obtained with the application of 90 kg N/ha. The per cent increase in green forage yield with the application of 30, 60 and 90 kg N/ha over control was 35, 53 and 75 respectively. The corresponding increase in dry matter yield was 30, 47 and 66 per cent over control. The most economical dose for sorghum was 67.23 kg N/ha.

Increasing levels of applied N indicated quadratic increase in green and dry matter production. Application of 90 kg N/ha to sorghum increased the dry matter yield by 193 per cent over control treatment. At lower level of

applied N (30-45 kg/ha) again the per cent increase in sorghum yield was about double than the other annual kharif fodder crops. The optimum dose of N worked out to be 141.6 kg/ha and the response to per kg of fertilizer N was 0.53 q/ha (Gill et. al., 1983).

Gupta et. al. (1986) reported that an increase in nitrogen level from 0 to 90 kg/ha increased the stover yield of sorghum cultivars from 1.12 to 2.54 t/ha. Byale et. al. (1987) found that increasing nitrogen rate from 0 to 160 kg/ha increased grain yield and nitrogen uptake of hybrid sorghum. Nitrogen use efficiency, however, decreased at higher levels of nitrogen fertilization.

Singh et. al. (1987) reported that the nitrogen content both in grain and stover increased significantly with increasing nitrogen levels from 0 to 100 kg N/ha. The total nitrogen uptake was also increased with increasing nitrogen levels. Bahl et. al. (1988) while studying the effect of nitrogen levels on different varieties of fodder sorghum found that seed yield was significantly increased when the nitrogen level was increased from 0 to 60 kg/ha. The applicaton of 60 to 90 kg N/ha increased the N, P and K uptake in sorghum plants during different growth stages and at harvest (Devasenapathy and Subburayalu, 1986).

Abdel-Raouf et. al. (1978) found that out of two years, N application from 0 to 30 kg/feddom significantly increased leaf area / plant, LAI and fresh fodder yield of

maize in only one year in Cairo. In field trials on an alluvial soil at Trifesti-Senbeni the CP content in maize grain increased with increase in N rate from 0-160 kg/ha but otimum yield was obtained at 120 kg N/ha. There was a positive interaction between N and P in increasing CP content (upto 96 kg P_2O_5) and yield (Albinet, 1978).

The positive effects of nitrogen nutrition on grain and stover yields of hybrid sorghums have been observed at 75 kg N/ha (Lanjewar and Knot, 1978), 100 kg N/ha (Patil and Jawale, 1977; Chaudhari, 1978) and 150 kg N/ha (Joshi and Upadhyay, 1977) under rainfed conditions of Maharashtra. In rainfed Bundelkhand region, however, the response has been observed upto 120 kg N/ha (Mehrotra et. al., 1979).

Effect of nitrogen application on forage quality

Nitrogen nutrition of crops not only increases the green and dry matter yields but also influences the quality of fodder, particularly the level of protein. The following effects of nitrogen on quality parameters have been observed (Mannikar, 1980).

(i) Optimum nitrogen nutrition improves leaf to stem ratio, succulency and palatability of forage crops,

(ii) Nitrogen application increased the crude protein, metabolizable energy and narrowed the nutritive ratio of fodder

(iii) Nitrogen applicaton increased the HCN content in fodder sorghum at 30th day of ratoon growth.

(iv) Higher dose of nitrogen application widened the ratio of true protein to NPN and increased the NO_3 content in oat fodder

The highest crude protein content with lowest percentage of dry matter and crude fibre were obtained in case of crop fertilized with 90 kg N/ha in 2 or 3 splits.

In forage sorghum cv. J-69 increasing N rates from 0 to 150 kg/ha increased the CF and CP content and decreased P content. HCN content increased upto 45 days of growth and decreased thereafter, fertilizers had no effect on HCN content (Khaddar et. al., 1985). Evaluation of 12 fodder sorghum cultivars including PC-21 and PC-28 revealed that the CP, fat, crude fibre and mineral matter decreased while carbohydrate content increased from the 1st to the 2nd and 3rd cut (Thakare et. al., 1987).

Mohammed and Hamid (1988) while studying the quality of hybrid forage sorghum reported that the forage cut during the vegetative stage had highest CP and ash contents, that cut at 50% flowering contained the highest percentage CF whereas that cut at the soft dough stage had the highest nonstructural carbohydrate content and gave highest protein yield. HCN concentration decreased as plants aged. Nitrogen application at 0, 80 and 160 kg/ha increased CP, ash and HCN content but decreased CF and non-structural carbohydrate content. CF and non-structural carbohydrate content was higher at the higher sowing rate.

Effect of nitrogen nutrition on HCN content

The epithelial cells of all sorghum species contain a glucoside, 'dhurrin' which liberates HCN when mixed with the enzyme beta-glucosidase formed only in mesophyll cells; bundle sheath strands contain neither 'dhurrin' nor the catabolic enzyme (Conn, 1980). There is no free HCN in plant and accordingly it is appropriate to refer to the hydrogen cyanide potential (HCNp) rather than the content of HCN. The HCNp of forage sorghum is usually in the range 100-800 ppm (dry matter basis) with occasional samples exceeding 1000 ppm. Factors affecting HCNp are plant age, genotype and temperature (Wheeler et. al., 1984) nitrogen, sulphur and phosphorus nutrition (Wheeler et. al., 1980), wilting (Nelson, 1953) and possibly light intensity (Harms and Tucker, 1973; Newton et. al., 1980). Sulphur fertilizer reduced HCNp substantially (Singh et. al., 1983). The consequences of HCNp poisoning relate to reduced acceptability of the forage to animals and the induction of sulphur deficiency. The advantages of routine supplementation with salt and sulphur are noted (Wheeler and Mulcahy, 1989).

The work done by Taneja et. al. (1983) revealed that increase in the level of nitrogen from 0 to 90 kg/ha increased the HCN content from 271.2 to 408.3 ppm at 30 days after sowing (DAS), 220.3 to 381.5 ppm at 45 DAS and from 153.5 to 247.2 ppm at 60 DAS in sorghum varieties. The average increase in HCN content worked out to be from 215.0 to 345.6 ppm. The increase in green and dry matter yields

were from 199.6 to 329.9 q/ha and from 36.3 to 67.8 q/ha at corresponding levels of fertilizer nitrogen. In another study, Raj and Patel (1988) found that increasing nitrogen rates from 40 to 100 kg/ha increased the average yields of sorghum cultivars from 10.14 to 11.70 t DM and from 0.52 to 0.84 t CP/ha but also increased HCN content from 2.9 to 5.4 mg/100 g DM.

Response of forage crops to sulphur nutrition

The response of forage crops to S application is reported by Beaton et. al. (1968) and Sisodia et. al. (1975). The optimum dose of sulphur for maximum forage production, however, varied with crop species, soil types, and other agroclimatic conditions. Dev and Arora (1984) reported that all categories of crops like cereals, legumes, oilseeds and pulses responded to applied sulphur but the magnitude of response was more in legumes than cereals. On the basis of several investigations, the optimum level of sulphur works out to be 27 ppm for berseem on alluvial soil of Uttar Pradesh (Bhardwaj and Pathak, 1969), 20 ppm for alfalfa in Punjab soil (Aulakh et. al., 1976), 30, 50, 25 kg/ha for berseem, maize and sarson, respectively on sandy loam soil (Gill et. al., 1986) and 40 kg/ha for Chinese cabbage on sandy clay loam soil (Tripathi and Hazra, 1988) of Bundelkhand. Gupta and Mehta (1980) found beneficial effect of 25 ppm sulphur application on fodder yield of berseem. The use of sulphur at 50 ppm and above showed no effect.

It has been suggested that the application rates of S to soils where individual crops are raised should be 2.5 times higher than the removal figures. Bodhe and Lande (1980) reported that in black soil of Maharashtra having 8 ppm available S, application of 50 kg S/ha resulted in an increase of sorghum yield by 3.3 per cent.

Forage quality in relation to sulphur nutrition

Since sulphur has a vital role in the synthesis of protein in the plants, it greatly contributes to the quality of forage crops. The increase in the outturn of crude protein with sulphur application has been reported in berseem (Pathak and Bhardwaj, 1968; Pasricha and Randhawa, 1972), tropical legumes and lucerne (Jones and Quagliato, 1970; Aulakh *et*. *al*., 1977), forage sorghum (Singh *et*. *al*., 1983) and Chinese cabbage (Tripathi and Hazra, 1988).

The change in sugar content with increasing rates of added sulphur caused an improvement in forage quality. Rending and McComb (1961) in alfalfa, and Jones *et*. *al*. (1970) in annual grasses observed that sugar level increased with the supply of sulphur mainly due to increased incorporation of CO_2 into glucose, fructose and sucrose. According to Tisdale (1977) increasing levels of sulphur in the rooting medium drastically reduced the amide N, and at the same time brought about a marked increase in the soluble sugar content in the young corn plants.

Zaroug and Munns (1980a) reported that sulphur application increased soluble sugar concentration due to

accelerated photosynthesis by imprving leaf area, enhancing CO_2 fixation and nitrogen metabolism. Peter et. al. (1987) showed tremendous increase in sugar content of rye grass resulting from inclusion of sulphur in the fertilizer schedule.

The better quality of forage is associated with higher contents of crude protein, ether extract and mineral matter and with less contents of NDF, ADF, hemicellulose and lignin. Verma and Singh (1987) observed that NDF and ADF were reduced under higher soil fertility conditions as a result of fertilization. Crops and their varieties differ considerably in forage quality. Leguminous fodder crops are better in quality having less content of NDF, ADF, hemicellulose, lignin and silica and higher amount of protein amino acid and minerals as compared to non-leguminous fodders (Singh and Mudgal, 1983; Singh and Narwal, 1987).

Effect of sulphur nutrition on HCN content

The characteristic feature of sorghum is to accumulate hydrocyanic acid (HCN) due to soil moisture stress which is toxic to animals if its concentration exceeds 250 ppm particularly during establishment stage (Hukkeri et. al., 1972). Earlier studies on nitrogen and phosphorus nutrition of forage sorghum indicate that higher dose of N caused an increase in HCN but that of P reduced its concentration (Shukla et. al., 1973). It is postulated

from such investigations that apart from the beneficial effect of P nutrition, the S contained in super-phosphate possibly plays an important role in reducing the HCN content. In alluvial soil of Madhya Pradesh (Singh et. al., 1983) found that herbage yield of sorghum cv. Jawahar-69 increased from 152.5 q/ha in untreated control to 280 q/ha with 50 kg P_2O_5 + 100 kg S/ha and to 303.8 q/ha with 100 kg S/ha without P. Herbage protein, sugar and fat contents also increased while HCN content markedly decreased with p and S fertilizers. Combined application of 100 kg S + 50 kg P_2O_5/ha ensured that sorghum fodder could be utilized safely after 20 days of growth. Other reports indicate reduction in HCN content of fodder sorghum (Shaik and Zende, 1972) and tapioca (Mohankumar and Nair, 1983) as a result of sulphur application.

Nutrient content in relation to sulphur nutrition

Sulphur fertilization improves the nitrogen and phosphorus concentration and their uptake in plants (Coldwell et. al., 1969; Robinson and Jones, 1972; Miyamoto et. al., 1974; Kumar and Singh, 1980).

Jones and Quagliato (1970) reported increasing trend in nitrogen concentration of plant as a result of applied sulphur in tropical pasture legumes. Similar beneficial effects of sulphur nutrition on nitrogen content in maize (Gaur et. al., 1971) and in mustard (Kataria and Shriniwas, 1976) have been obtained.

Aulakh _et_. _al_. (1977) observed increasing trend in nitrogen content with added sulphur, while those of total soluble N, amide N and nitrate N decreased. Zaroug and Munns (1980b) showed that nitrogen concentration was raised by sulphur fertilization, and combined application of phosphorus and sulphur lowered plant nitrate content. The critical value of sulphur in plants has been reported as 0.24 per cent (Fox _et_. _al_., 1964) in sweet corn, 0.12 to 0.30 per cent (Sorensen _et_. _al_., 1968) and 0.18 to 0.24 per cent (Westermann, 1974) in alfalfa. McLarn (1975) surveyed the sulphur content of soils and herbages in South East Scotland and found that in many soils, sulphur levels were too low to support optimum growth of herbage without addition of sulphur. The S concentration increased remarkably by the addition of sulphur. Similar observation with added S are reported by Singh _et_. _al_. (1979), Raikhy _et_. _al_. (1985) and Tripathi and Hazra (1988) in some of the fodder crops. Gupta and Mehta (1980) observed a marked increase in sulphur concentration of berseem at 25 ppm which decreased at 50 ppm and above. Aggarwal _et_. _al_. (1985) also observed similar effect of sulphur fertilization on sulphur content and its uptake by cowpea. They suggested 10 ppm sulphur application for getting highest removal by the crop. The excess supply of sulphur beyond 10 ppm S had no effect. Moreover, a significant reduction was observed at 40 ppm S where sulphur concentration was comparable with that in control treatment.

N:S ratio in relation to nitrogen and sulphur nutrition

N:S ratio in plant is a much reliable measure of the sulphur requirement than the absolute level of sulphur. Several workers have reported that the ratio varies with the composition of plants (Dijkshoorn et. al., 1960; Dijkshoorn and Van Wijk, 1967). They suggested that any change in the supply of nitrogen and sulphur leads to the accumulation of non-protein nitrogen (in case of excess nitrogen or sulphur deficiency) or non-protein sulphur (in case of excess sulphur or nitrogen deficiency), which causes change in the N:S ratio. According to Oconnor and Vartha (1969) high N:S ratio indicated a deficiency of sulphur and low ratio adequacy of sulphur or possibly deficiency of nitrogen.

The application of sulphur influenced N:S ratio upto a critical level beyond which sulphur was not needed for the crops. According to Pumphery and Moore (1965) and Pumphery (1967) the N:S ratio 11:1 or below, indicated an adequate sulphur supply and produced maximum yield of alfalfa. Dijkshoorn and Van Wijk (1967) proposed that when N:S ratio is above 16:1, sulphur deficiency causing limited protein formation could be expected, and sulphur fertilization will be required. The N:S ratio below 14:1 to 16:1 showed accumulation of non-protein sulphur in the plant which indicated inferiority of fodder quality.

N:S ratio in the fodder crops could be adjusted according to the requirement of sulphur in the animal feed. Arora (1986) reported optimum N:S ratio of 10:1 to 15:1 for ruminants, and suggested that when the ratio is wider than 20:1, the cattle are not likely to utilize the forage properly and efficiently.

Effect of nitrogen and sulphur interaction

The interrelationship of nitrogen a primary plant nutrient corresponds to its secondary counterpart sulphur in determining their desired ratio in herbage material to meet the nutritional requirement of animals. Since N and S are closely linked in protein metabolism, their relationship is reported to be synergistic. These two nutrients are often found to increase the concentration and uptake of each other. Application of S in the absence of N decreased the N concentration in brassica plants, when N was added with S the effect was synergistic (Hazra, 1988). However, nitrogen content in Chinese cabbage was found to increase marginally with S application but such an increase was significant in the presence of N.

Singh and Singh (1987) studied the effect of 0-120 kg N and/or 0-120 kg S/ha on fodder yield and quality of sorghum grown on a sandy loam soil. Increasing N rates to 120 kg and S rates to 80 kg/ha increased fresh fodder and DM yields, and CP, P, K and S contents; N+S gave further significant increases in CP, K, P and S contents, but not in fodder yield.

Studies on grain and silage maize with 0, 10, 20 or 40 lbs S/acre as gypsum and 0, 75, 150 or 225 lbs N/acre as urea revealed that sulphur application increased grain yield at all the sandy sites and at 2 of 8 sites with a silt loam soil. Application of 10 lbs was adequate for optimum grain yield at 3 of 4 sites where there was a positive response to S fertilizer. S application had no significant effect on DM yield at any site. There was no NxS interaction for either DM or grain yield. N but not S application increased silage C.P. content but neither N nor S had a significant effect on silage ADF or NDF content (O'Leary and Rehm, 1990).

At Indian Grassland and Fodder Research Institute, Jhansi increasing levels of nitrogen from 30 to 90 kg/ha increased the forage yields of M.P. Chari significantly and the mean dry matter accumulation was 9.1 and 11.1 tonnes/ha at 30 and 90 kg respectively. Similarly, the relative leaf turgidity increased from 73.1 to 78.4 per cent at the corresponding levels of fertilizer nitrogen. Though the differences in yield due to sulphur doses were statistically not significant but the highest green (35.8 t/ha) and dry matter (10.8 t/ha) yields were obtained at 40 kg S/ha. The relative leaf turgidity at this level was 77.3 per cent against 73.8 per cent under control treatment. In this way the highest forage yield in sorghum

cv. M.P. Chari was obtained by maintaining the soil moisture regime at 75% available soil moisture (ASM) and fertilizing the crop with 90 kg N/ha. Beneficial effect of 40 kg sulphur/ha was, however, observed in the rainfed and 50% ASM treatments indicating more conspicuous responses to nirogen and sulphur under sub optimal moisture regimes (Menhi Lal and Shukla, 1990).

On the basis of the work at National Dairy Research Institute, Karnal, Khezhie et. al. (1979) reported that application of N at 75 kg/ha produced significant effect in green and dry matter yields of fodder mustard but S levels upto 15 kg/ha did not exercise such effect. The crude protein content and yield significantly increased with increasing levels of N from 25 to 75 kg/ha and S levels from 0 to 15 kg/ha. The interaction was also significant. Nitrogen at 75 kg/ha increased S content, however, S did not influence its composition in the fodder.

Tripathi and Hazra (1988) observed that nitrogen and sulphur application each @ 40 kg/ha gave significantly higher forage yield as well as nutrient uptake than the highest nitrogen level of 60 kg N/ha without sulphur application. However, the maximum forage yield and uptake of nitrogen and sulphur were obtained at highest level of nitrogen (60 kg N/ha) and sulphur (40 kg S/ha).

MATERIALS AND METHODS

MATERIALS AND METHODS

The materials used and techniques employed in field investigation and laboratory estimations have been described in the following sections:

Experimental site and soil characteristics:

The investigation was conducted during kharif (rainy) season of 1988 and 1989 at the Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (UP). The soil of the experimental field represented Parwa soil group of Bundelkhand region. As per soil taxonomy, the soil is covered under the order Entisol. Parwa soil, a kind of mixed red and black soil, represents the characteristics of medium soil. The composite soil samples from 0-15 cm depth were collected before the start of the experiment and subjected to physico-chemical analyses (Table 1). The soil of the experimental field was sandy clay loam in texture and neutral in reaction. The soil analysed low in organic carbon, available nitrogen and sulphur, medium in available phosphorus and high in available potassium.

The soil is medium in water holding capacity and prone to crust formation following rains. These soils fail to support plant growth if drought prevails for 2-3 weeks even under mild evaporative demand.

Table 1. Physico-chemical characteristics of the soil from experimental field

Characteristics		Methods used
Mechanical composition		Bouyoucos hydrometer method (Bouyoucos,1962)
Sand (%)	48.2	
Silt (%)	21.6	
Clay (%)	30.2	
Textural class	sandy clay loam	
Soil molisture characteristics		Pressure plate apparatus method
Field capacity (%)	24.4	
Wilting point (%)	8.5	Pressure memb-rane method (Richards,1954)
Bulk density (g/cc)	1.40	Core sampler method (Piper, 1950)
Available moisture (mm/metre profile depth)	222.6	
Physico-chemical properties		Combined glass electrode pH meter (Jackson,1958)
Soil pH (1:2.5)	7.5	
Electrical conductivity at 25°C (mmhos/cm)	0.16	Solubridge method (Richards,1954)
Organic carbon (%)	0.48	Walkley & Black's method(Jackson,1958)
Available nitrogen (kg/ha)	200	Alkaline $KMnO_4$ method (Subbiah & Asija,1956)
Available phosphorus (kg P/ha)	18.70	Olsen's method (Olsen. et.al.,1954)
Available potassium(kg K/ha)	394	Flame photometer method (Toth and Prince, 1949)
Available sulphur (ppm)	8.5	Turbidity method (Chesnin and Yien, 1951)

Weather Conditions:

Jhansi is situated at $25^{O}27'$ North of latitude and $78^{O}35'$ East of longitude, 271 metres above mean sea level in semi-arid tract of Central India. The rainfall ranges from 800 to 1100 mm with annual mean of 936 mm. The moisture index varies from -40 to -60. A critical analysis of the rainfall pattern of Jhansi district indicates that the rainfall is highly erratic and more than 90% of the rainfall is received from June to September with several intermittant long dry spells. The total rainfall is received in about 46 rainy days. The winter showers are meagre and highly unpredictable. The drought is a rule rather than an exception. At Jhansi, drought in the months of June and September is expected once in 12 years. The monsoon rains normally commence by the end of June but sometimes is delayed to the first week of July. Usually the active monsoon withdraws by mid September.

The average annual temperature of the place is uniformly high and there is considerable variation in maximum temperatures. May and June experience the highest temperature sometimes touching the value of $47.8^{O}C$. Such a high temperature coupled with windy days results in an annual potential evapotranspiration of 1400 - 1700 mm. This often causes standing crops to wilt even though the soil moisture regime may not be very low. The average seasonal potential evapotranspiration

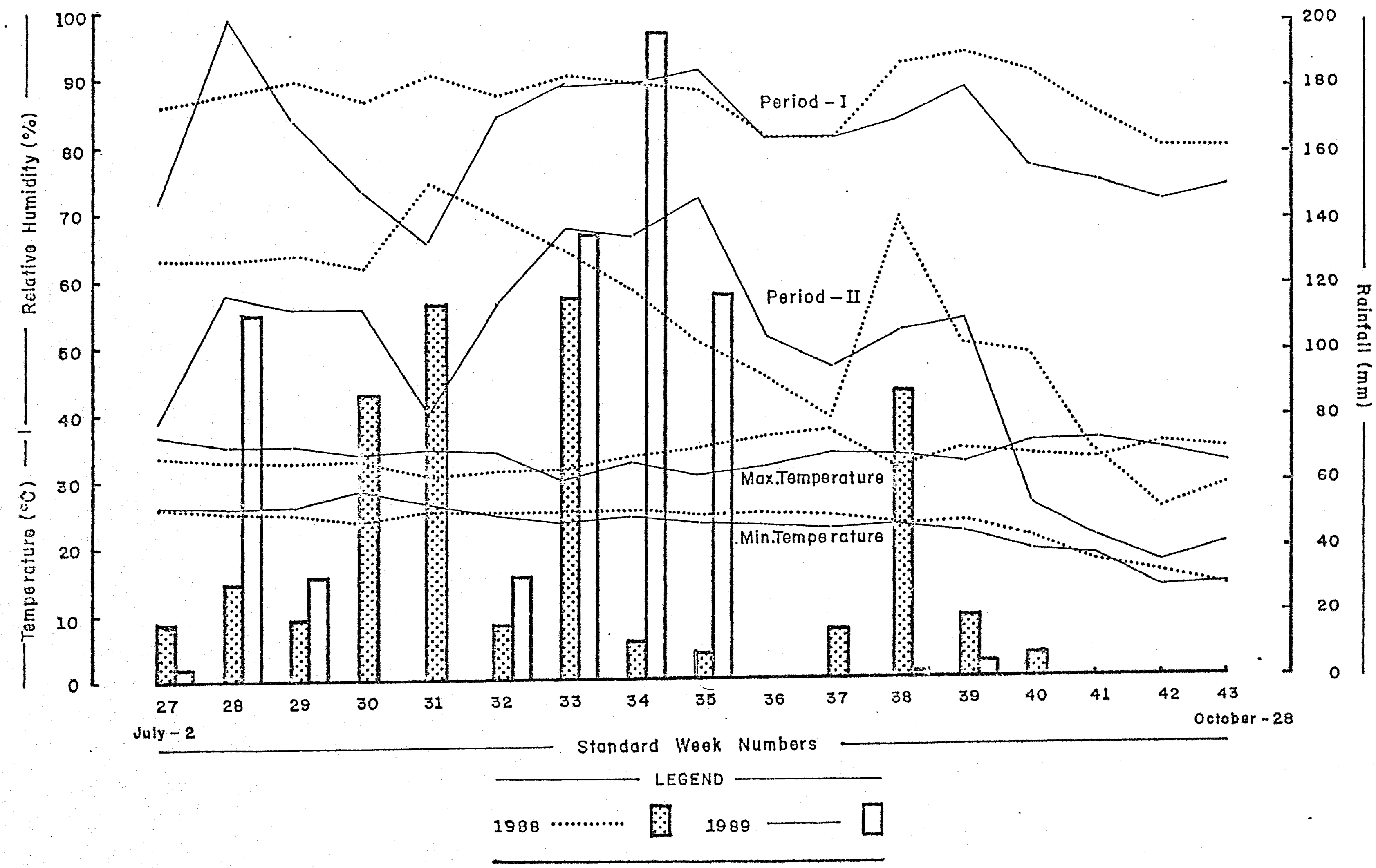
from July to October is of the order of 511 mm coinciding with rainy season crops. The mean weekly values of meteorological parameters for crop period are presented in Table 2 and depicted in Fig. 1.

The meteorological data would reveal that during crop period the rainfall received was 556.3 mm in 1988 and 634.3 mm in 1989. Though the total rainfall was higher in 1989 but its distribution was better in 1988. The year 1988 faced drought in the standard week 36 beginning from September 3 and monsoon ceased from standard week 41 starting from October 8. On the contrary the year 1989 experienced two critical dry spells each of two weeks duration coinciding with standard weeks 30/31 (July 23 to August 5) and 36/37 (September 3 to 16). The withdrawal of monsoon occurred at the end of standard week 39 i.e. September 30. These rains were received in 35 days in 1988 against in 21 days in 1989 indicating that rains were more intense during second year. The maximum and minimum temperatures ranged between 30.7 to 38^{o}C and 14.5 to 26.0^{o}C in 1988 and between 30.4 to 36.9^{o}C and 14.1 to 28.8^{o}C in 1989, respectively. The relative humidity in 1988 for periods I and II varied from 81 to 95 and 26 to 75%. The corresponding figures for 1989 were 66 to 99 and 18 to 73%.

Table 2. Weekly mean meteorological data for crop periods in 1988 and 1989

Week beginning on		Standard week No.	Temperature (°C)				Relative humidty (%)				Rainfall (mm)		No. of rainy days	
			Maximum		Minimum		Period I		Period II					
			1988	1989	1988	1989	1988	1989	1988	1989	1988	1989	1988	1989
July	2	27	33.7	36.9	26.0	25.5	86	72	63	39	17.9	4.5	1	-
	9	28	33.0	35.2	25.5	26.1	88	99	63	58	30.9	110.4	4	3
	16	29	32.7	35.4	25.3	26.3	90	84	64	56	19.6	31.9	4	3
	23	30	33.2	34.1	24.0	28.8	87	74	62	56	87.1	0	5	0
	30	31	30.7	34.8	25.5	26.6	91	66	75	40	114.2	0	6	0
August	6	32	31.4	34.5	25.2	25.1	88	85	70	57	17.6	31.5	2	3
	13	33	32.1	30.4	25.2	24.3	91	90	65	68	116.2	134.7	3	3
	20	34	34.0	32.8	25.7	25.1	90	90	59	67	12.6	195.5	1	3
	27	35	35.5	30.9	25.1	24.1	89	92	51	73	8.6	117.0	1	5
September	3	36	37.1	32.7	25.6	23.7	82	82	46	52	0	0	0	0
	10	37	38.0	34.6	25.2	23.3	82	82	40	47	15.7	0	1	0
	17	38	32.5	34.0	23.8	24.2	93	85	70	53	88.4	2.5	4	-
	24	39	35.4	32.9	23.9	22.7	95	90	51	55	19.3	6.3	1	1
October	1	40	34.6	36.3	22.1	19.8	92	78	50	27	8.2	0	2	0
	8	41	34.0	36.5	18.0	18.8	86	76	35	22	0	0	0	0
	15	42	36.3	34.9	16.2	14.1	81	73	26	18	0	0	0	0
	22	43	35.5	33.3	14.5	14.1	82	75	30	21	0	0	0	0
	29	44	34.0	33.0	14.6	13.0	82	77	22	20	0	0	0	0
Total											556.3	634.3	35	21

FIG. 1 : WEEKLY MEAN METEOROLOGICAL DATA FOR CROP PERIODS IN TWO YEARS



Cropping history of the experimental field:

The cropping history of the experimental field is detailed below:

Year	Kharif	Rabi
1987-88	Cowpea	Oat
1988-89	Forage sorghum (experimental crop)	Oat
1989-90	-do-	Oat

Field preparation and experimental layout:

The experimental field was thoroughly prepared by ploughing with cultivator and cross discing with disc harrow followed by planking. Layout for the experiment was done by demarcating drainage channels and plot bunds. The individual plots were perfectly levelled to ensure good seed beds for sorghum crop.

Experimental details

Treatments

A. Sorghum varieties (V) : 3

PC-6	V_1
HD-2	V_2
HC-136	V_3

B. Nitrogen levels (N) : 3

30 kg N/ha	N_1
60 kg N/ha	N_2
90 kg N/ha	N_3

C. Sulphur levels (S) : 3

0 kg S/ha	S_1
15 kg S/ha	S_2
30 kg S/ha	S_3

Total treatment combinations		: 27
Experimental design		: 3^3 partial confounding
Replication		: Two with 6 blocks each of 9 plots.
Total number of plots		: 54
Plot size :	Gross	: 5m x 4m = 20 m^2
	Net	: 4m x 3m = 12 m^2

The treatment combinations were allocated to different plots using Fisher and Yate's random table. The plan of layout is depicted in Fig. 2.

Varietal characteristics:

Pusa Chari - 6 (PC-6): This variety was notified in the year 1980 for the whole country with a yield potential of 500 q/ha green forage and 165 q/ha dry matter. It is non-sweet, pithy and non-juicy and flowers in 85-90 days. Leaves are medium, long and broad with white midrib. Panicle is semi-compact with bold and white seeds. It matures in 135-140 days and gives 8-9 q/ha seed yield.

Hybrid Derivative-2 (HD-2): This was notified for the whole country in 1985 possessing the yield level of 450-500 q/ha green forage. It flowers in 65-70 days and matures in 110-115 days. It is a medium stemmed and juicy variety. leaves are long with light green colour. Panicle is oval shaped and compact. Grains are medium bold, round and pearly white in colour. It gives 6-8 q/ha seed yield.

Haryana Chari - 136 (HC-136): HC-136 was notified for release in 1982 for the whole country. It possesses very

FIG. 2: PLAN OF LAYOUT

N

	VNS	VNS	VNS	VNS	VNS	VNS	
	323	222	211	313	133	121	
B3	321	233	113	322	331	223	B6
	132	121	312	211	112	232	
	111	313	212	311	131	332	
B2	133	321	122	221	113	323	B5
	332	223	231	122	233	212	
	131	333	221	222	111	333	
B1	123	213	112	231	213	321	B4
	311	232	322	312	132	123	5m
		R1			R2	4m	

V - Varieties (1-PC-6, 2-HD-2, 3-HC-136)
N - Nitrogen levels (1-30, 2-60, 3-90 Kg N/ha)
S - Sulphur levels (1-0, 2-15, 3-30 Kg S/ha)

R1 - R2 Replications
B1 - B6 Blocks

high yield potential of 550 q/ha green forage and 175 q/ha dry matter. This variety is tall, sweet, juicy and medium stemmed. The leaves are very broad and long with green midrib and remain green upto maturity. It has maximum field tolerance to leaf-spot diseases. Panicle is compact. It possesses high protein, free toxic constituents and better digestibility. It flowers in 95-100 days and matures in 135-145 days. It yields 10-12 q/ha seed. Seed is bold and white.

Fertilizer Schedules

Nitrogen, as per the treatments, was applied in the form of diammonium phosphate (DAP) containing 18% N and 46% P_2O_5 and urea containing 46% N as per the details given below:

Nitrogen levels	Dose (kg/ha) at sowing through		Topdressing of N (kg/ha) through urea
	DAP	Urea	
30 kg N/ha	18	0	12
60 kg N/ha	18	22	20
90 kg N/ha	18	42	30

The above fertilizer schedule provided 46 kg P_2O_5/ha uniformly to all the plots at sowing. Sulphur was applied as per the treatments in the form of 85% sulphur powder. The basal dose of fertilizers as per the above schedule was placed in the furrows below the seed. The remaining dose of nitrogen in different treatments was topdressed by mixing urea with friable moist soil 20 days after sowing.

Sowing

Sorghum varieties PC-6, HD-2 and HC-136 were sown in 25 cm apart rows using a seed rate of 40 kg/ha through kera method on July 9 in 1988 and July 19 in 1989. After a week thinning and/or gap filling was done to maintain adequate and uniform plant population.

Crop Management

As an effective weed management practice atrazine @ 0.75 kg a.i./ha in 600 litres of water was applied as pre-emergence. The crop was maintained under rainfed environment. During the period of heavy rains, however, excess water was drained off to provide well drained conditions.

Harvesting

The crop was harvested plotwise for green forage by manual labour with the help of sickle - as and when a particular variety attained 50% flowering stage. The harvesting schedules for different varieties in two years were as follows:

Varieties	Harvesting dates	
	1988	1989
PC-6	3.10.88	12.10.89
HD-2	17.9.88	27.9.89
HC-136	17.10.88	27.10.89

Thus, the crop duration for sorghum varieties PC-6, HD-2 and HC-136 worked out to be 85, 70 and 100 days, respectively.

Observations recorded:

Growth characters:

The observations on growth characters were recorded at forage stage before harvesting the crop. The following biometrical measurements were taken on five plants randomly selected from each plot.

Plant height: The height of five plants was measured in centimetres and averaged out. The height measurement was taken from ground level to the base of fully opened leaf and/or to the base of panicle depending upon the stage of a particular plant.

Number of functional leaves: The green leaves of all the five plants were counted and reported as number of functional leaves per plant.

Length and breadth of leaves: For these measurements, third leaf from the top was selected from five plants on which height measurement was taken. The maximum length and the breadth of such leaves were measured in centimetres.

Leaf area: The area of individual leaf was determined by using the following expression given by Yogeswara Rao *et al.* (1966).

Leaf area = Length x breadth x 0.75

Leaf:Stem ratio: At harvest, the plants drawn for the above plant characters were also utilized for the determination of leaf:stem ratio. For this, the leaves were separated out from the stem (shoot). The fresh

weights of leaves and stem were recorded separately. The leaf weight was divided by stem weight to arrive at leaf: stem ratio.

Relative leaf turgidity percentage:

The relative turgidity percentage or relative water content (RWC) of leaves was determined by the method of Shaw and Laing (1966). For this the third leaf from the top was taken as the representative one. Such leaves from three plants per plot were sampled at harvest and their fresh weight was recorded. These leaves were dipped in water overnight to allow them to become fully turgid. After taking out from water, the turgid weight was recorded. The leaves were then dried in oven at 80°C for constant weight. Finally, the dry weight was taken and the relative turgidity percentage was calculated by the following formula:

$$\text{Relative turgidity percentage} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

All the weights were expressed in grams.

Plant water stress:

Plant water stress was measured plotwise in terms of Tc - Ta values in replication I at canopy surface using Infra-red Thermometer (Model AG 42) between 12 Noon to 2 PM. These observations were taken on three dates (August 30, September 5 and 14) in 1988 and on two dates (September 12 and October 7) in 1989 coinciding with the critical dry spells.

Dry matter content:

At harvesting,plant samples weighing 200 grams were collected from each plot in paper bags. These samples were dried in hot air oven at 80°C for 48 to 72 hours to get constant weight. After taking the dry weights, the dry matter percentage was computed.

Green forage yield:

After harvesting, the produce was weighed in kilograms for net plot size. The yields obtained from individual plots were converted and expressed as green forage yield in q/ha.

Dry matter yield:

The plotwise data on green forage yield were multiplied with corresponding dry matter percentage to obtain dry matter yield in kg/plot which was later on converted to q/ha.

Chemical analysis:

Crude protein (CP), hydrocyanic acid (HCN) and water soluble carbohydrates (WSC) contents were determined at fortnightly intervals beginning from 25 days after sowing till the harvest of crop. These parameters, therefore, were determined six time including at harvesting stage each year following the procedures detailed below.

Plant sampling and processing:

Plants numbering 4-5 from net plot area were cut randomly and chopped at field site into small pieces to get about 500 g sample from all the plots in replication I for estimation of nitrogen and hence crude protein. At harvesting stage of each variety, however, the treatmentwise composite samples from both the replications were prepared and drawn up. The chopped samples were mixed thoroughly and kept in polythene bags immediately to avoid moisture loss before carrying to the laboratory. From this lot 200 g sample was taken for dry matter estimation. A portion of the sample from individual plot was crushed into fine pieces and mixed well in 'Mixie' to obtain representative samples for the analysis of the following quality parameters.

Crude protein (CP): The total nitrogen content in the plants was determined by Micro-Kjeldahl method (A.O.A.C., 1970). Fresh samples weighing 2.0 g were transferred to Kjeldahl flasks and digested in 10 ml of concentrated H_2SO_4 using catalyst mixture (K_2SO_4 and $CuSO_4$ in the ratio of 20:1). The digested material was transferred to 50 ml volumetric flask with distilled water and the volume was made up to the mark. An aliquot of 5 ml was distilled with 40% NaOH and the ammonia liberated was absorbed in 10 ml of 4% boric acid containing Tashano's indicator (Bromocresol green and methyl red). The distillate was titrated with

standard (N/10) H_2SO_4. Nitrogen was calculated using the expression 1 ml of N/10 H_2SO_4 = 0.0014 g of nitrogen and the crude protein content was computed by multiplying the nitrogen percentage with a factor of 6.25.

Water soluble carbohydrates (WSC): The content of water soluble carbohydrates was determined by the method of Johnson et al. (1966). To determine the content of water soluble carbohydrates in plants, 2.0 g of fresh samples were ground with 100 ml of distilled water in a 'Mixie'. Then, 1 g of activated charcoal was added and the contents were filtered. From the filtrate, an aliquot of 2 ml was taken in a test tube and 2 drops of phenol (80%) and 5 ml of concentrated H_2SO_4 were added to it. After shaking, the tubes were allowed to stand for 20 minutes with a second shaking at 10 minutes interval. The optical density was measured on Spectronic-20 Spectrophotometer at 490 mμ and the concentration of water soluble carbohydrates was determined from the standard curve.

Hydrocyanic acid (HCN): Hydrocyanic acid content of the plant sample was determined by the method of Hogg and Ahlgren (1942).

0.30 g of freshly harvested and finely crushed sample was placed in a test tube and 3-4 drops of chloroform was added to it. Now a moist test paper strip (a filter paper strip of 10.0 cm x 0.5 cm size saturated

with alkaline picrate solution prepared by dissolving 25 g of Na_2CO_3 and 5 g of picric acid in 1 litre of water) was suspended and the tube was corked properly. After an incubation period of 24 hours at room temperature, the strip was taken out and transferred to another tube containing 10 ml of water. The intensity of the colour developed was measured at 520 m μ wave length using Spectronic-20 Spectrophotometer and the concentration of HCN was determined from the standard curve prepared with KCN solution.

Determination of fibre fractions:

Processing of plant samples

The plotwise samples on which dry matter determination was undertaken, were ground into fine powder by 'Wiley mill'. Twenty seven composite samples were prepared by thoroughly mixing the samples of the corresponding treatment combinations from both the replications. These samples were subjected to the estimation of fibre fractions in duplicate and the values were averaged out. The procedures for estimation of various fibre fractions are described below:

Neutral detergent fibre (NDF): The neutral detergent fibre was determined by the method of Van Soest and Wine (1967). A 0.5 g dried, ground sample was weighed in 600 ml spoutless beaker. To this, 100 ml of neutral detergent solution (30 g sodium lauryl sulphate, 18.61 g EDTA, 6.81 g

sodium tetraborate decahydrate and 4.56 g disodium hydrogen phosphate and 10 ml 2-ethoxy-ethanol in 1 litre distilled water) and 2 ml of Decalin (decahydronaphthalin) and 0.5 g of sodium sulphate were added. The contents were refluxed for 60 minutes and filtered into a tared sintered glass crucible (porosity G1). The contents were washed repeatedly with hot water followed by acetone twice. The crucibles were dried at 100°C for 24 hrs in a thermostatically controlled hot air oven, weighed and the NDF expressed as per cent on dry weight basis.

Acid detergent fibre (ADF): The acid detergent fibre was determined by Van Soest method (1963). The procedure for ADF estimation was similar to NDF estimation except that 2.0 g sample was taken instead of 0.5 g and acid detergent solution (2% solution of cetytrimethyl ammonium bromide in 1N H_2SO_4) was used in place of neutral detergent solution.

Acid detergent lignin (ADL): Acid detergent lignin was determined by the method of Van Soest (1963). To the ADF residue in the crucible, 72% sulphuric acid was added to cover the contents. The crucible was then stirred with glass rod to make a smooth paste, breaking all lumps. The glass rod remained in the crucible and stirring continued at an hourly intervals by adding 72% H_2SO_4 as and when it drained out. The crucible was then kept at 20-23°C for 3 hrs. After 3 hrs, the acid was filtered with a vacuum and the contents were weighed with hot water to make it acid free. The crucible was dried at 100°C for 24 hrs and weighed. The contents of the crucible were ashed at 600°C

in muffle furnace for 3 hrs, cooled at room temperature in desiccator and weighed. Lignin was expressed as per cent on dry matter basis.

Hemi-cellulose and cellulose:

These fibre fractions were computed using the following formulae:

Hemi-cellulose = Neutral detergent fibre-Acid detergent fibre

Cellulose = Acid detergent fibre-Acid detergent lignin

Sulphur content in plant:

The estimation of sulphur was taken up for the same processed samples on which the estimation of fibre fractions was done.

Sulphur content in the plant samples was determined turbidimetrically using the method of Chesnin and Yien (1951). To the 0.5 g of oven dried and powdered plant material taken in 100 ml conical flasks, 5 ml of conc. HNO_3 was added and the material was digested for half an hour on a hot plate at low temperature. Then, 5 ml of di-acid mixture of HNO_3 and $HClO_4$ (9:2 ratio) was added and digested till a white clear solution was obtained.

After cooling the residue was washed with distilled water and filtered through Whatman filter paper No. 42 in a 50 ml volumetric flask and the volume was made up to the mark.

For the development of turbidity, an aliquot of 5 ml was taken in a 25 ml volumetric flask and 10 ml of

sodium acetate - acetic acid buffer was added to it. Now, 4 ml of 25% $BaCl_2$ solution (equivalent to 1 g $BaCl_2$) was added and flask was shaken thoroughly for one minute. Then, 2 ml of 0.25% gum acacia solution was added and volume was made up. After thorough shaking, the intensity of turbidity was measured on Spectronic-20 Spectrophotometer at 530 mμ wave length and the concentration of sulphur was determined from standard curve prepared in the similar fashion using standard sulphur solution.

N:S ratio:

The N:S ratio in forage at harvest stage was determined by dividing the nitrogen percentage with sulphur percentage of the plant samples from the corresponding treatments.

Nutrient uptake:

The uptake of nitrogen and sulphur at harvest stage was computed treatmentwise by multiplying dry matter yields with the corresponding nutrient contents and the values were expressed in kg/ha.

Statistical analysis

Analysis of variance and test of significance:

The data on various growth characters at harvest and forage yields were subjected to statistical analysis by the method of "Analysis of Variance" as advocated by Fisher

(1948). However, the data on quality parameters pertaining to single replication were statistically analysed as in case of factorial experiment treating the M.S. due to VNS (8 d.f.) as error. The two factor interactions were tested for significance.

The data on hydrocyanic acid (HCN) content were subjected to statistical analysis after 'Square root transformation' as follows:

$$\sqrt{x} \quad \text{or} \quad \sqrt{x + \frac{3}{8}} \quad \text{(In case of zero value)}$$

where x = HCN in ppm

The significance of treatment effect was tested with the help of variance ratio (F value). The values of SEm $\pm$ and critical difference (CD) were worked out by the following formulae for judging the significance of difference between two treatment means

$$\text{SEm} \pm = \sqrt{\frac{VE}{n}}$$

where VE = Error variance ; n = Number of observations

Critical difference (CD) = $\sqrt{2}$ x SEm X t at 5% for error degree of freedom.

Fitting of response functions

In order to determine the nature of response of sorghum varieties to levels of nitrogen and sulphur, linear and quadratic components were tested for significance. The response equations were developed and curves fitted by the techniques of least square difference.

Graphical representation of data:

The data obtained on various aspects under the investigation have suitably been depicted through graphs, histograms and curves wherever necessary to illustrate the experimental findings.

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

This chapter embodies the results of the investigation and delineates the influence of nitrogen and sulphur levels on various growth attributes and forage yield of sorghum varieties. The data on crude protein, water soluble carbohydrates and hydrocyanic acid contents determined at different crop growth stages, fibre fractions, nutrient contents and their ratio in plants at harvesting stage to assess the forage quality in relation to treatment variables have been presented and interpreted. This section also includes the data on nutrient uptake and response functions/ equations for sorghum varieties in relation to fertilizer nitrogen and sulphur.

Growth and development of crop

Plant height:

The data on plant height for both the years have been presented in Table 3 and depicted in Fig. 3.

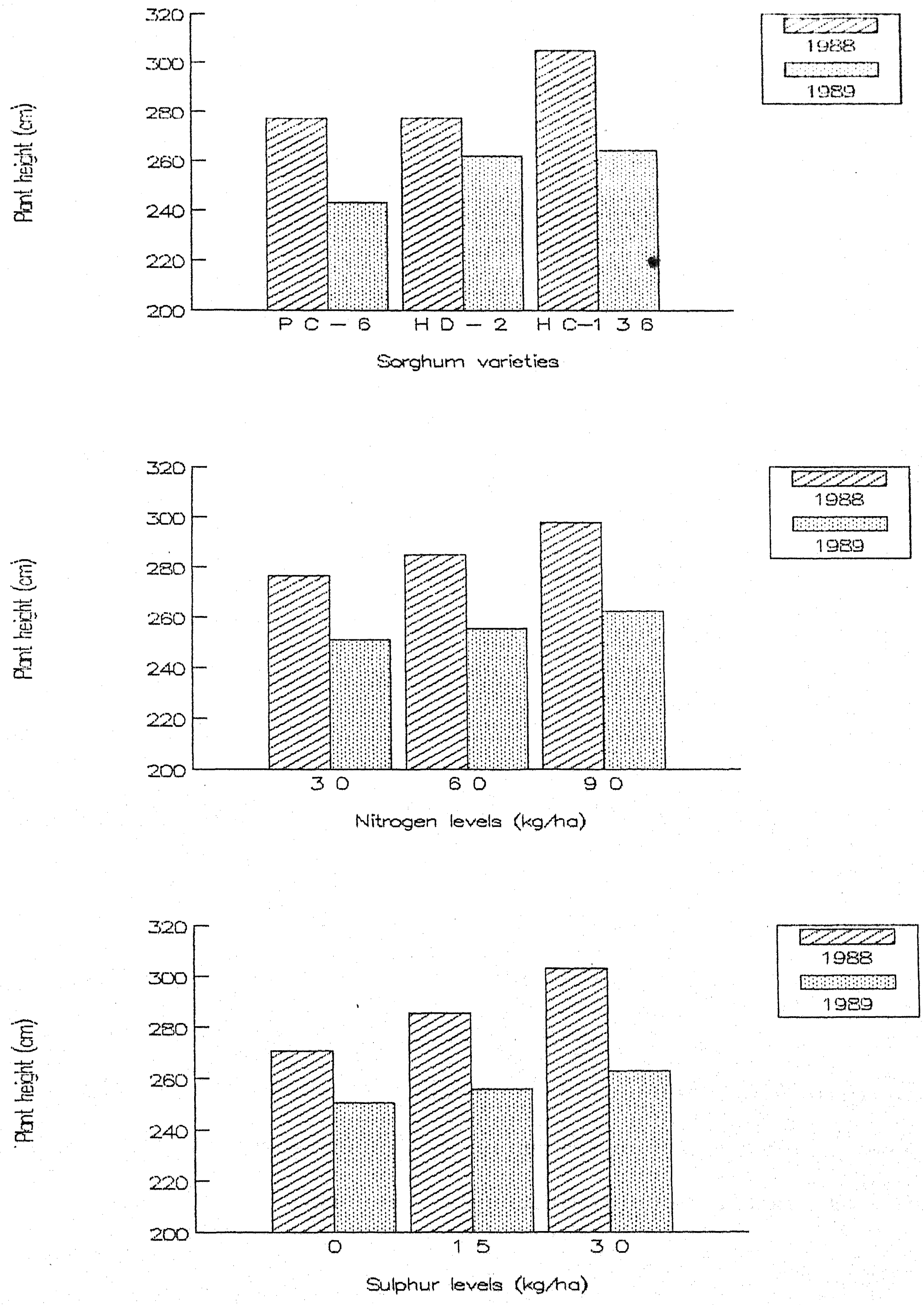
A perusal of the data would reveal that the plants attained more height in 1988 (286.6 cm) than in 1989 (256.3 cm). There was a significant variation in plant height among the varieties in both the years. In 1988, variety HC-136 significantly excelled PC-6 and HD-2 which produced practically the same height. In 1989, again variety HC-136 produced significantly taller plants than PC-6 but statistically at par with HD-2.

Table 3. Plant height (cm) and number of functional leaves/plant

Treatments	Plant height (cm)		Number of functional leaves	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	277.3	242.8	8.0	5.8
HD-2	277.5	262.1	6.0	5.7
HC-136	304.8	264.1	8.7	6.4
SEm $\pm$	5.95	3.23	0.25	0.13
CD at 5%	17.5	9.5	0.7	NS
Nitrogen levels (kg/ha)				
30	276.8	250.9	7.0	5.7
60	284.9	255.6	7.6	6.0
90	297.9	262.5	8.2	6.3
SEm $\pm$	5.95	3.23	0.25	0.13
CD at 5%	NS	NS	0.7	0.4
Sulphur levels (kg/ha)				
0	270.9	250.5	7.2	5.8
15	285.6	255.9	7.6	6.0
30	303.0	262.6	7.9	6.1
SEm $\pm$	5.95	3.23	0.25	0.13
CD at 5%	17.5	9.5	NS	NS
General Mean	286.6	256.3	7.6	6.0

NS = Non-significant

FIG 3: PLANT HEIGHT (cm)



Nitrogen did not exercise significant effect on plant height in both the years. The increasing levels of nitrogen from 30 to 90 kg N/ha, however, increased the plant height from 276.8 to 297.9 cm in 1988 and from 250.9 to 262.5 cm in 1989.

Sulphur nutrition had a positive effect on plant height in both the years. However, the successive differences in plant height were not significant. But the application of 30 kg S/ha produced significantly taller plants than the control treatment.

The interaction V x N x S significantly influenced the plant height in 1988 (Table 4) with the result that tallest plants were recorded in variety HC-136 when fertilized with 60 kg N and 30 kg S/ha. This was, however, at par with treatment combinations consisting of PC-6 and HC-136 receiving 60 and/or 90 kg N/ha and 30 kg S/ha. Variety HD-2 fertilized with 30-90 kg N and 30 kg S/ha produced statistically similar plant height.

<u>Number of functional leaves</u>:

It is evident from the data (Table 3 and Fig. 4) that in the year 1988, number of functional leaves per plant was comparatively more (7.6) than in 1989 (6.0).

Among the three sorghum varieties, HD-2 had the lowest number of functional leaves. It differed significantly from PC-6 and HC-136 which were at par in 1988. However, in 1989 there was no significant variation in these varieties.

FIG 4: NO.OF FUNCTIONAL LEAVES/PLANT

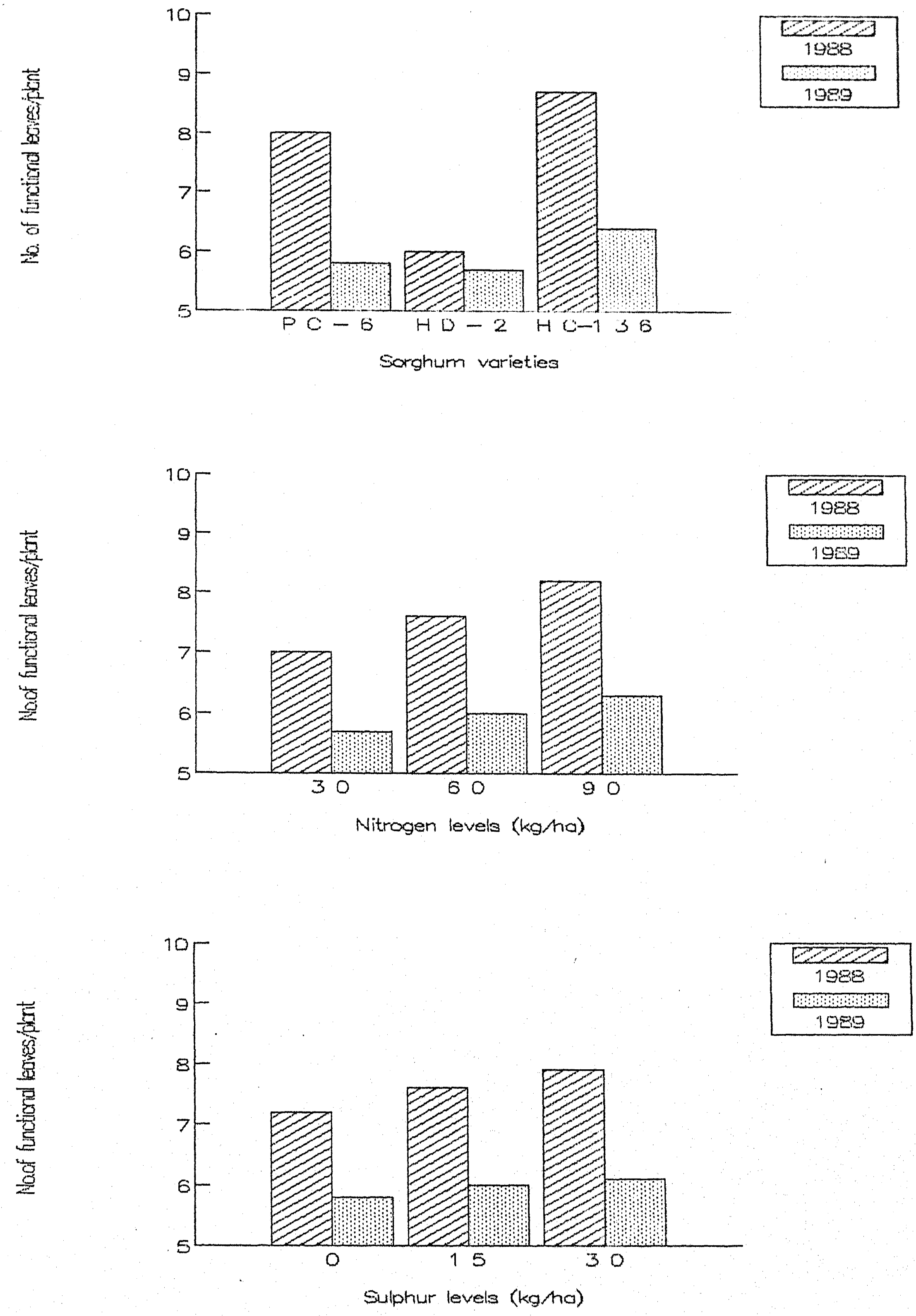


Table 4. Effect of VxNxS interaction on plant height (cm) in 1988

Sulphur (kg/ha)	Varieties								
	PC - 6			HD -2			HC - 136		
	Nitrogen (kg/ha)								
	30	60	90	30	60	90	30	60	90
0	258.9	237.8	284.7	305.2	297.8	290.5	262.3	243.7	257.6
15	272.5	291.0	268.4	290.3	291.2	328.2	273.7	245.0	300.3
30	257.0	311.1	317.2	301.5	318.4	309.8	269.4	327.8	317.5

SEm ± 17.86

CD at 5% 52.4

Application of nitrogen showed a significant effect on the number of functional leaves per plant at harvest stage. Plants fertilized with 90 kg N/ha maintained significantly higher number of leaves as compared to those receiving 30 kg N/ha during both the years.

Sulphur nutrition had no marked effect on the number of functional leaves as it did not show any significant variation with the increasing levels of sulphur application in both the years.

Leaf length: The data presented in Table 5 and Fig. 5 indicate that plants had comparatively longer leaves in 1988 than in 1989. Sorghum variety HD-2 had significantly longest leaves as compared to PC-6 and HC-136 which were statistically at par during both the years of experimentation.

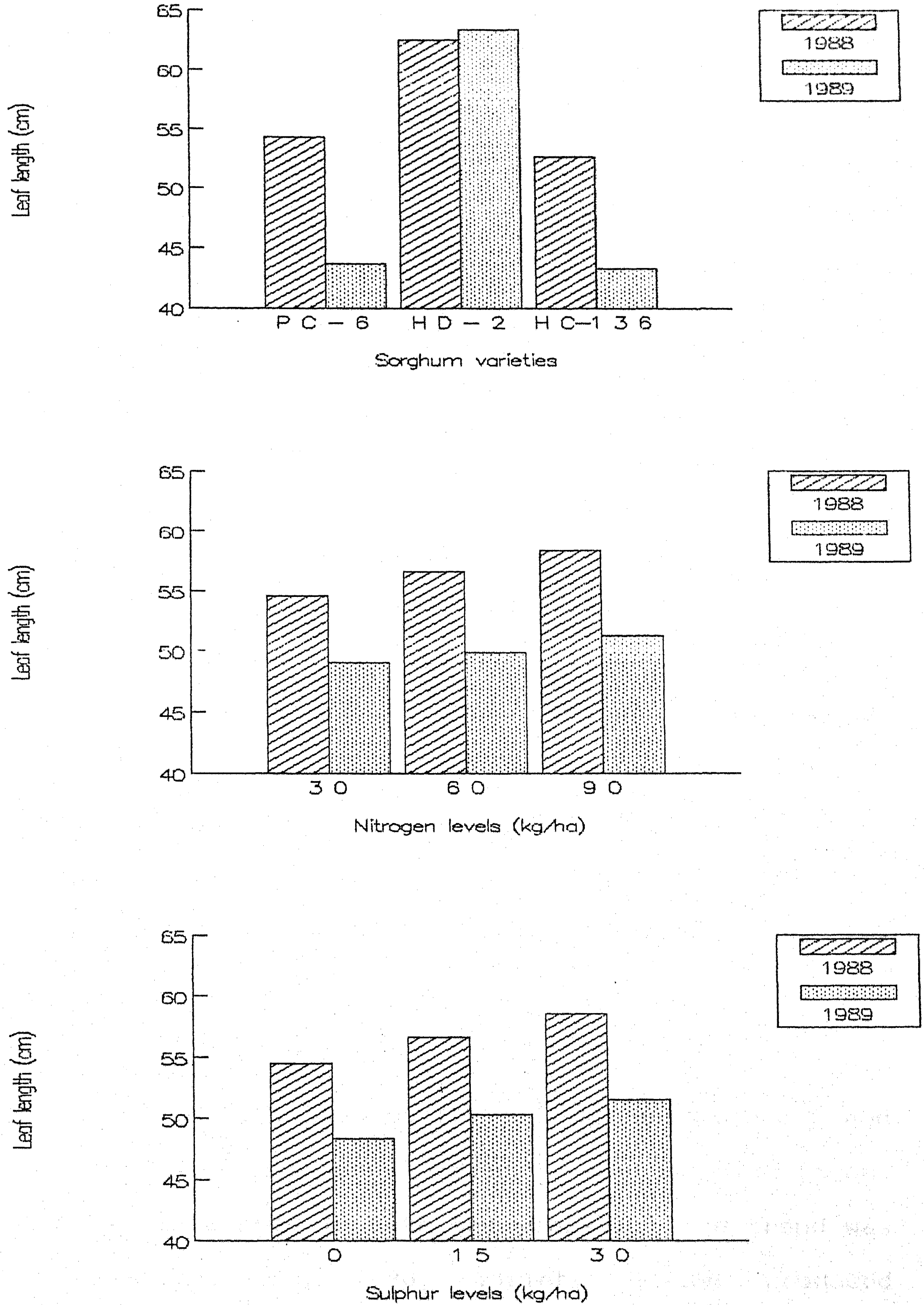
Nitrogen nutrition had a positive effect on the leaf length, however, it was not statistically significant in 1989. In the year 1988, application of 90 kg N/ha produced significantly longer leaves (58.4 cm) as compared to 30 kg N/ha (54.6 cm). However, successive differences were not significant.

Sulphur application increased the leaf length in both the years, however, the effect was statistically non-significant in 1989. In 1988, 30 kg S/ha produced significantly longer leaves (17.7 cm) over control but

Table 5. Leaf length and breadth (cm)

Treatments	Leaf length (cm)		Leaf breadth (cm)	
	1988	1989	1988	1989
<u>Sorghum varieties</u>				
PC-6	54.3	43.7	5.6	4.7
HD-2	62.5	63.3	4.7	4.6
HC-136	52.7	43.3	6.5	4.8
SEm ±	0.98	0.94	0.15	0.10
CD at 5%	2.9	2.8	0.4	NS
<u>Nitrogen levels (kg/ha)</u>				
30	54.6	49.1	5.4	4.5
60	56.6	49.9	5.6	4.6
90	58.4	51.3	5.8	4.9
SEm ±	0.98	0.94	0.15	0.10
CD at 5%	2.9	NS	NS	0.3
<u>Sulphur levels (kg/ha)</u>				
0	54.5	48.4	5.2	4.5
15	56.6	50.4	5.6	4.7
30	58.5	51.6	5.9	4.8
SEm ±	0.98	0.94	0.15	0.10
CD at 5%	2.9	NS	0.4	NS
General Mean	56.5	50.1	5.6	4.7

FIG 5: LEAF LENGTH (cm)



did not differ significantly from 15 kg S/ha. In 1989, leaf length increased from 20.2 cm in control to 22.2 cm in 30 kg S/ha.

<u>**Leaf breadth**</u>: The data on leaf breadth (Table 5 and Fig.6) would reveal that the plants produced broader leaves (5.6 cm) in 1988 than in 1989 (4.7 cm). In 1988, the differences in leaf breadth among sorghum varieties were significant and HC-136 had significantly broader leaves as compared to other varieties. In 1989, however, the varieties did not exhibit significant variation in leaf breadth.

Nitrogen nutrition exercised significant effect on leaf breadth in 1989 only when application of 90 kg N/ha produced broadest leaves. This was statistically at par with 60 kg N/ha which in turn did not differ from 30 kg N/ha. In 1988, though the broadest leaves were obtained with 30 kg S/ha but it did not differ statistically from 15 kg S/ha which ofcourse was at par with control treatment. In 1989, the application of sulphur did not bring out significant differences in leaf breadth.

<u>**Leaf area**</u>: The average leaf area of the individual leaf was 234.8 cm^2 in 1988 against 175 cm^2 in 1989 (Table 6 and Fig. 7). The sorghum varieties showed significant variation in leaf area in both the years but the trend was quite different. In 1988, variety HC-136 produced

FIG 6: LEAF BREADTH (cm)

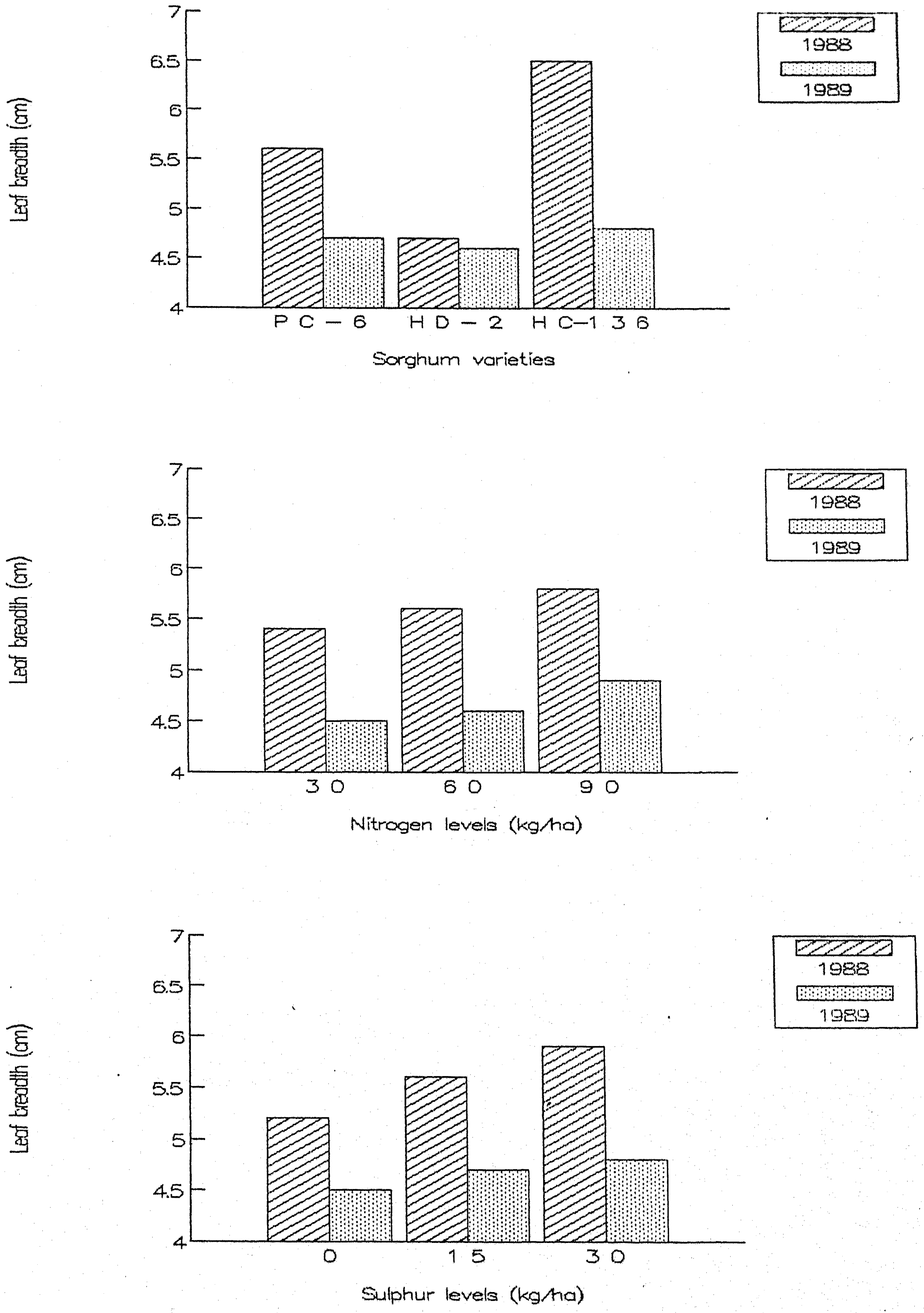
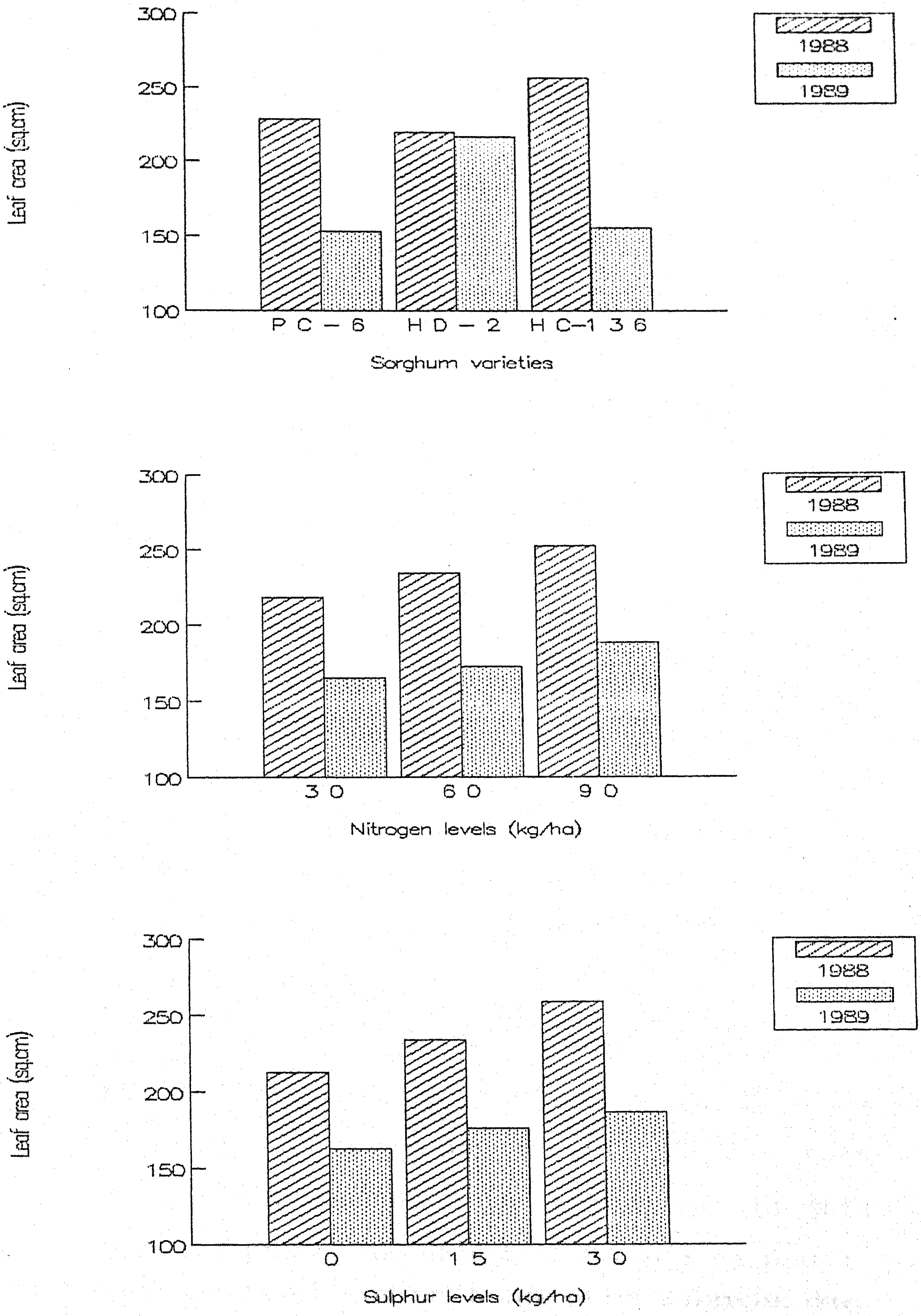


Table 6. Leaf area (cm^2 .) and leaf : stem ratio

Treatments	Leaf area (cm^2)		Leaf : stem ratio	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	228.4	153.0	0.23	0.18
HD-2	219.5	216.4	0.15	0.17
HC-136	256.5	155.5	0.17	0.16
SEm $\pm$	6.81	4.84	0.01	0.004
CD at 5%	20.0	14.2	0.03	0.01
Nitrogen levels (kg/ha)				
30	218.3	164.7	0.17	0.16
60	234.1	172.6	0.19	0.17
90	252.1	187.7	0.19	0.18
SEm $\pm$	6.81	4.84	0.01	0.004
CD at 5%	20.0	14.2	NS	NS
Sulphur levels (kg/ha)				
0	212.4	162.6	0.20	0.17
15	233.6	176.1	0.18	0.17
30	258.5	186.4	0.17	0.17
SEm $\pm$	6.81	4.84	0.01	0.004
CD at 5%	20.0	14.2	NS	NS
General Mean	234.8	175.0	0.18	0.17

FIG 7: LEAF AREA (sq.cm)



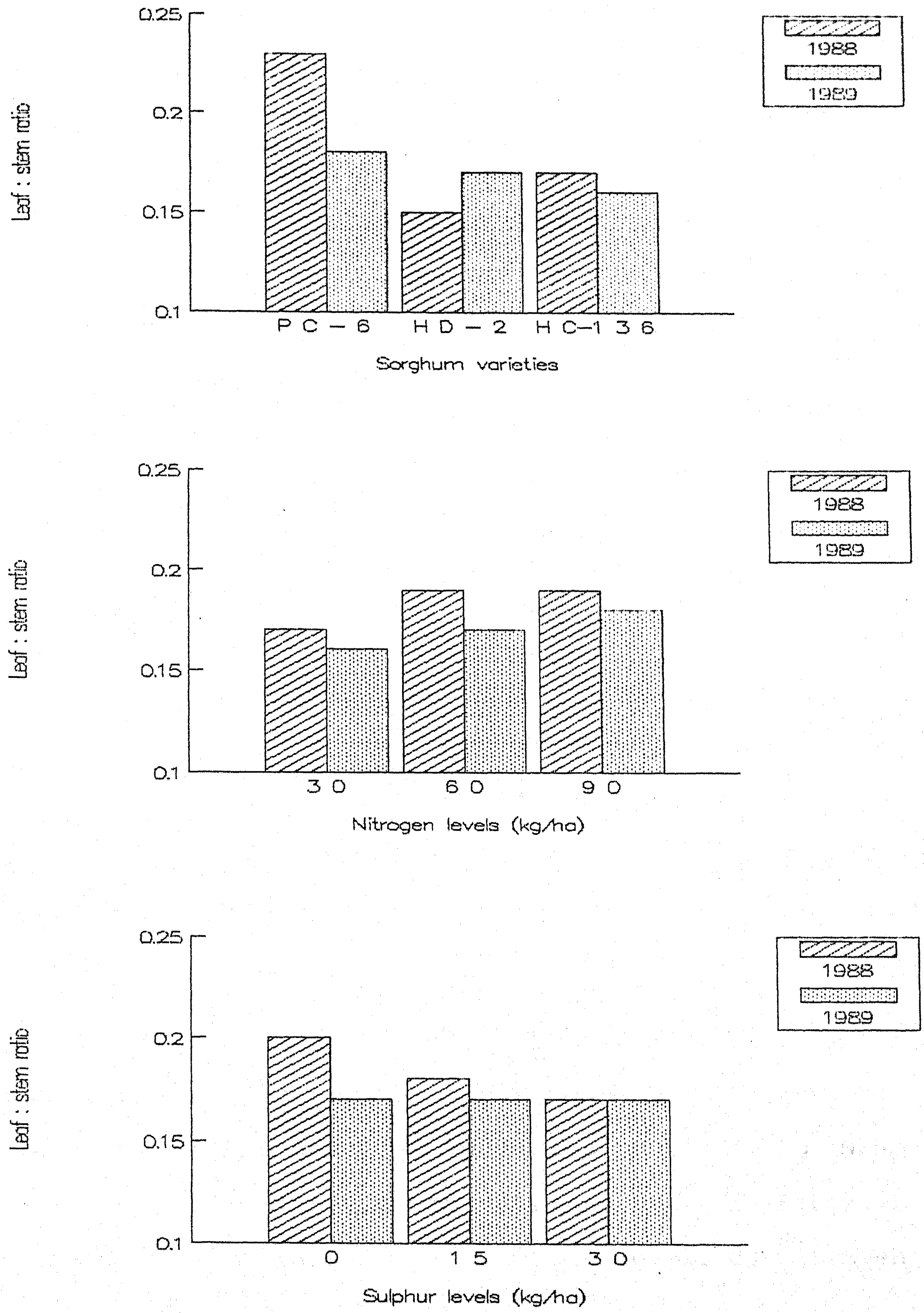
significantly greater leaf area as compared to PC-6 and HD-2 which were at par between themselves. In 1989, however, HD-2 gave significantly highest leaf area over HC-136 and PC-6 which produced practically similar leaf area.

The leaf area was significantly influenced by nitrogen fertilization in both the years. In 1988 though the increasing doses of nitrogen tangibly improved the leaf area but the successive difference did not reach the level of significance. In 1989, application of 90 kg N/ha produced significantly higher leaf area over 30 and 60 kg N/ha which were statistically at par between themselves.

In 1988, the successive difference in leaf area due to increasing doses of sulphur was significant. In 1989, application of 30 kg S/ha produced significantly higher leaf area over control treatment but did not differ materially from 15 kg S/ha.

Leaf : Stem ratio: The data on leaf : stem ratio are presented in Table 6 and Fig. 8. A perusal of the data would reveal that leaf : stem ratio remained practically the same in two years (0.17-0.18). In 1988 variety PC-6 exhibited significantly greater leaf : stem ratio as compared to remaining varieties whereas in 1989 it was at par with HD-2. HC-136 and HD-2 did not differ in this respect in both the years. The effect of N and S on leaf : stem ratio was not significant. However, N widened but S narrowed down the ratio.

FIG 8: LEAF : STEM RATIO



Relative leaf turgidity:

The data on relative turgidity per cent (relative water content) determined at harvest have been presented in Table 7 and depicted in Fig. 9. The average relative leaf turgidity was 86.0 per cent in 1988 and 80.1 per cent in 1989. The sorghum varieties exhibited considerable differences in relative leaf turgidity in both the years. Varieties HC-136 and PC-6 were at par between themselves but significantly superior to HD-2.

The relative leaf turgidity increased progressively with increasing levels of nitrogen but differences between 30 and 60 and between 60 and 90 kg N/ha were statistically not significant in 1988. In 1989, however, the doses differed significantly from each other.

The sulphur fertilization also caused an increase in relative leaf turgidity in both the years. In 1988,the use of 30 kg S/ha proved significantly superior over control treatment but statistically at par with 15 kg S/ha. In 1989 the successive differences were, however, significant.

In 1989, the varieties interacted significantly in influencing the relative leaf turgidity (Table 8) with the result that variety HC-136 fertilized with 90 kg N/ha exhibited significantly highest relative leaf turgidity of 85.3 per cent as compared to HD-2 at all levels of nitrogen and PC-6 at 30 kg N/ha.

Table 7. Relative leaf turgidity (%)

Treatments	1988	1989
Sorghum varieties		
PC-6	88.8	83.0
HD-2	78.2	73.6
HC-136	90.3	83.8
SEm ±	1.17	0.61
CD at 5%	3.4	1.8
Nitrogen levels (kg/ha)		
30	83.3	77.4
60	85.4	79.8
90	88.7	83.2
SEm±	1.17	0.61
CD at 5%	3.4	1.8
Sulphur levels (kg/ha)		
0	83.5	77.8
15	85.5	79.9
30	88.4	82.7
SEm ±	1.17	0.61
CD at 5%	3.4	1.8
General Mean	86.0	80.1

FIG 9: RELATIVE LEAF TURGIDITY (%)

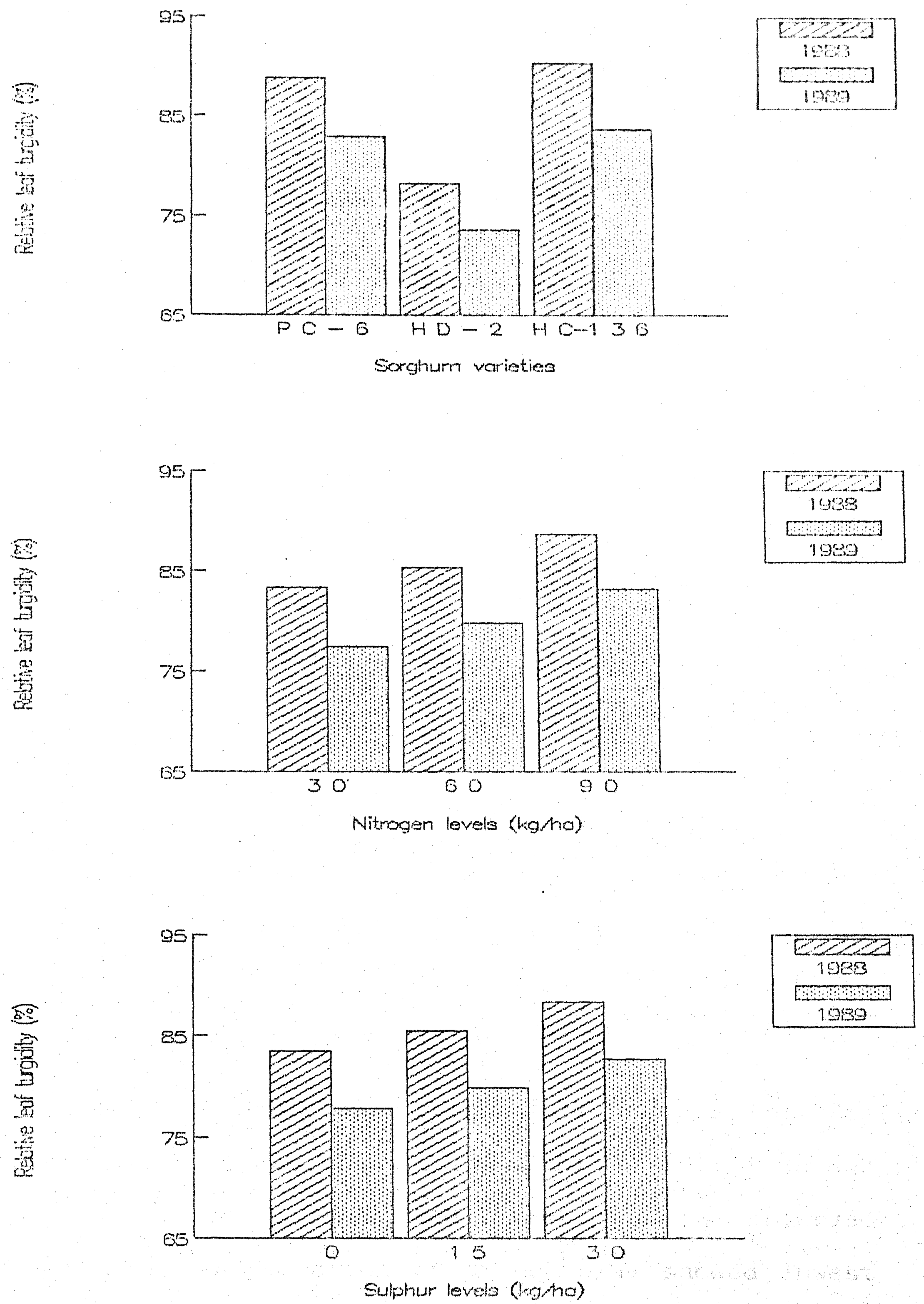


Table 8. Effect of V x N interaction on relative leaf turgidity (%) in 1989

Nitrogen (kg/ha)	Varieties		
	PC-6	HD-2	HC-136
30	80.1	70.0	82.1
60	84.3	71.1	84.0
90	84.7	79.7	85.3

SEm ± 1.06

CD at 5% 3.1

Plant water stress (Tc-Ta)

The data on the difference between canopy and atmospheric temperatures (Tc-Ta values) measured during critical drought spells are presented in Table 9. In general Tc-Ta values increased from -3.71 to -1.95^{o} at various stages in 1988. The differences in Tc-Ta values due to varieties, nitrogen and sulphur were statistically not significant in both the years. However, variety HD-2 continued to show lowest Tc-Ta values at all the points of measurement followed by PC-6. Variety HC-136 exhibited greater Tc-Ta values throughout.

Increasing doses of nitrogen from 30 to 90 kg N/ha progressively increased the values of Tc-Ta on 30.8.88 and 5.9.88. On 14.9.88, however, the lowest value was observed at 60 kg N/ha. Application of 15 kg S/ha showed lowest

Table 9. Plant water stress (Tc-Ta °C) in 1988 and 1989

Treatments	1988			1989	
	30.8.88	5.9.88	14.9.88	12.9.89	7.10.89
Sorghum varieties					
PC-6	-3.19	-3.14	-1.67	-2.82	-5.62
HD-2	-4.77	-3.38	-2.20	-3.90	-
HC-136	-2.77	-2.28	-1.28	-2.91	-6.68
SEm ±	0.377	0.411	0.320	0.366	
CD at 5%	NS	NS	NS	NS	
Nitrogen levels (kg/ha)					
30	-4.09	-3.17	-1.72	-3.51	-3.85
60	-3.60	-2.93	-1.81	-3.44	-4.19
90	-3.04	-2.69	-1.61	-2.67	-4.26
SEm ±	0.377	0.411	0.323	0.366	
CD at 5%	NS	NS	NS	NS	
Sulphur levels (kg/ha)					
0	-3.18	-2.77	-1.41	-2.93	-3.24
15	-3.82	-3.02	-2.32	-3.39	-5.26
30	-3.73	-3.00	-1.41	-3.30	-3.80
SEm ±	0.377	0.411	0.323	0.366	
CD at 5%	NS	NS	NS	NS	
General Mean	-3.71	-2.98	-1.95	-3.20	-

Tc-Ta values during all the drought spells followed by 30 kg S/ha. The maximum Tc-Ta and in turn plant water stress was observed in control treatment.

In 1989 also variety HD-2 exhibited lowest Tc-Ta value (-3.90^{o}C) on 12.9.89. The difference between HC-136 (-2.91^{o}C) and PC-6 (-2.82^{o}C) was, however, not much. On 7.10.89, HD-136 recorded lower Tc-Ta (-6.68^{o}C) as compared to PC-6 (-5.62^{o}C). Nitrogen nutrition increased Tc-Ta values on 12.9.89, but the trend was reversed on 7.10.89. The lowest Tc-Ta values were observed with 15 kg S/ha at both the stages of measurement followed by 30 kg S/ha. The plants in control plots exhibited greater Tc-Ta values.

The interactions V x N and V x S were found to be significant (Table 10). The increasing levels of nitrogen increased the plant water stress in PC-6 and HD-2 but decreased in HC-136. On the other hand, sulphur nutrition lowered down the plant water stress in PC-6 and HC-136 but did not alter much in HD-2.

Forage yield:

The data on green forage and dry matter yields for both the years have been presented in Table 11 and depicted in Fig. 10 and 11.

Green forage yield: The perusal of the data would reveal that the level of green forage production was higher in

Table 10. Effect of V x N and V x S interaction on plant water stress (Tc-Ta ^{o}C) on 30.8.1988

Nitrogen (kg/ha)	Varieties			Sulphur (kg/ha)	Varieties		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136
30	-4.33	-5.52	-2.43	0	-2.48	-4.97	-2.08
60	-3.48	-4.27	-3.05	15	-4.42	-4.67	-2.38
90	-1.75	-4.53	-2.83	30	-2.67	-4.68	-3.85

SEm $\pm$	0.653	SEm $\pm$	0.653
CD at 5%	2.13	CD at 5%	2.13

Table 11. Green forage and dry matter yield (q/ha)

Treatments	Green forage yield (q/ha)		Dry matter yield (q/ha)	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	323.4	311.9	113.9	109.5
HD-2	328.9	319.3	109.8	109.6
HC-136	443.9	371.6	150.9	131.8
SEm ±	8.00	3.60	3.20	1.65
CD at 5%	23.4	10.6	9.4	4.8
Nitrogen levels (kg/ha)				
30	319.2	297.6	107.4	96.8
60	360.2	335.0	124.2	118.2
90	416.8	370.2	143.0	135.8
SEm ±	8.00	3.60	3.20	1.65
CD at 5%	23.4	10.6	9.4	4.8
Sulphur levels (kg/ha)				
0	334.9	288.3	114.3	100.1
15	365.7	335.0	123.7	116.7
30	395.6	379.4	136.5	134.1
SEm ±	8.00	3.60	3.20	1.65
CD at 5%	23.4	10.6	9.4	4.8
General Mean	367.4	334.2	125.0	116.6

FIG 10: GREEN FORAGE YIELD (q/ha)

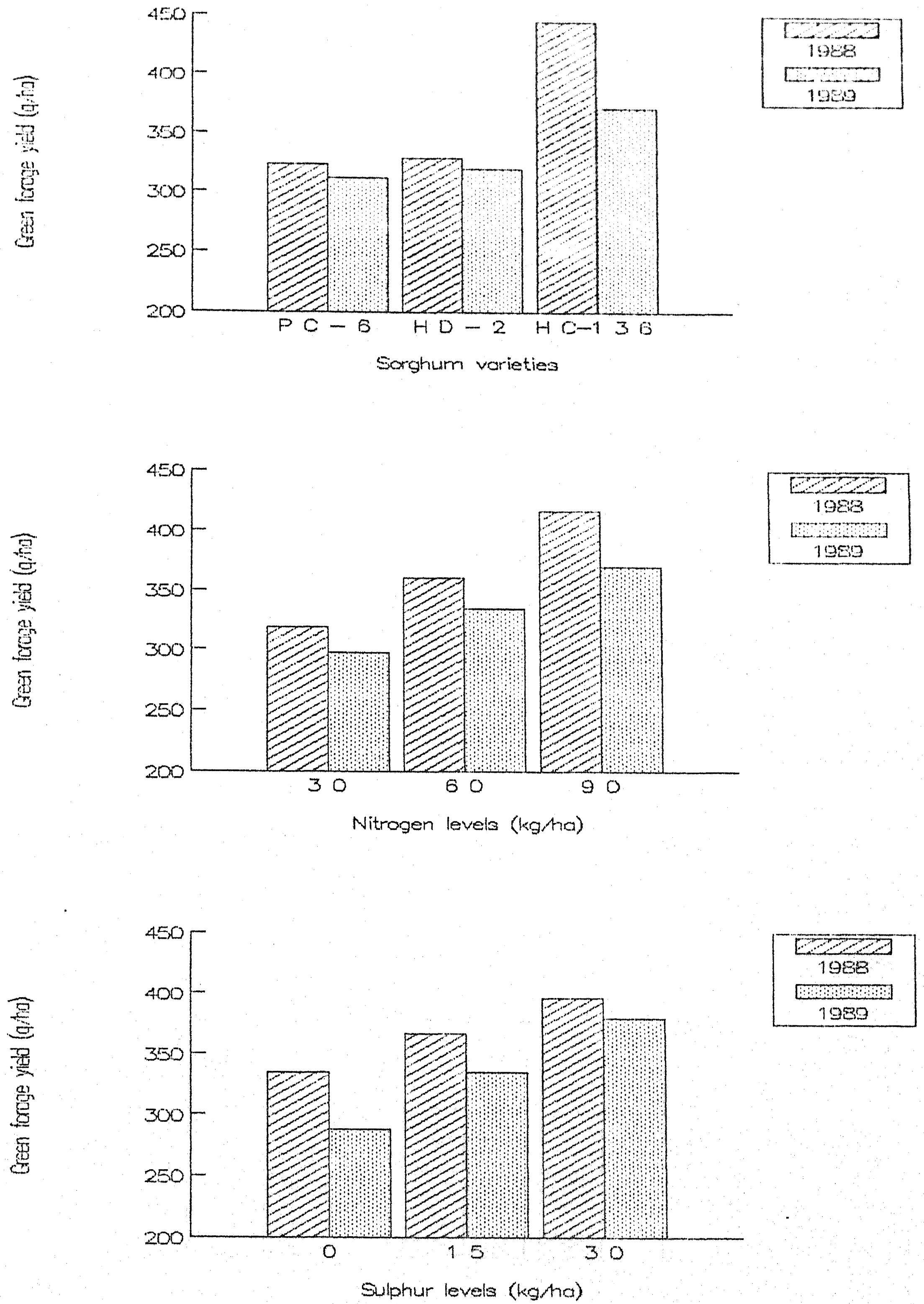
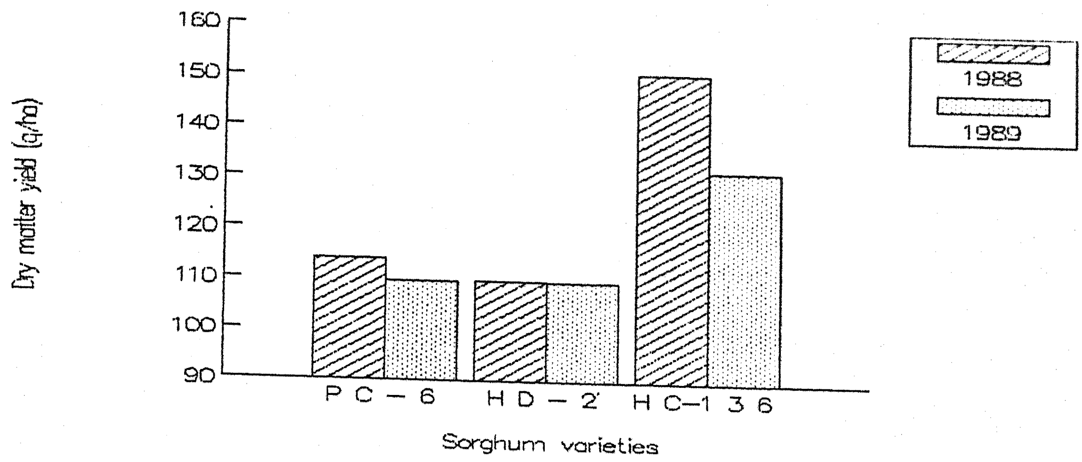
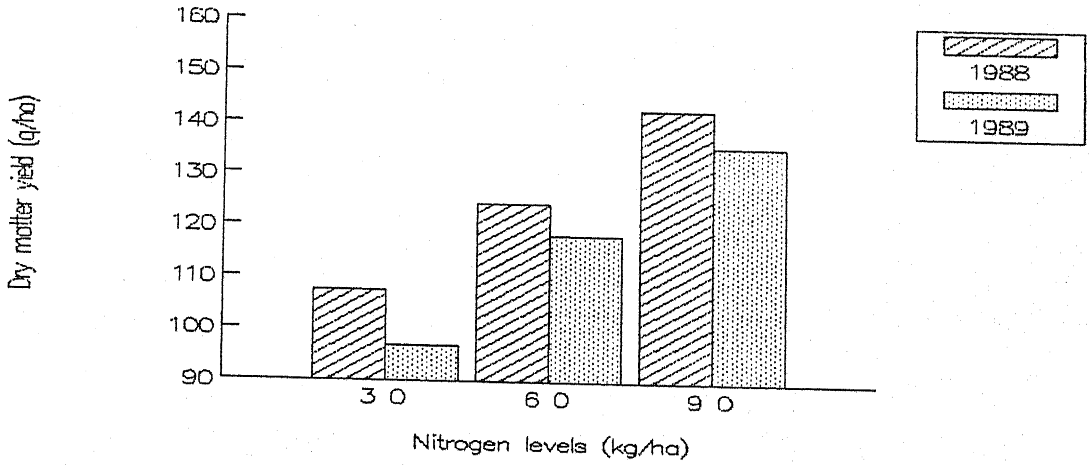
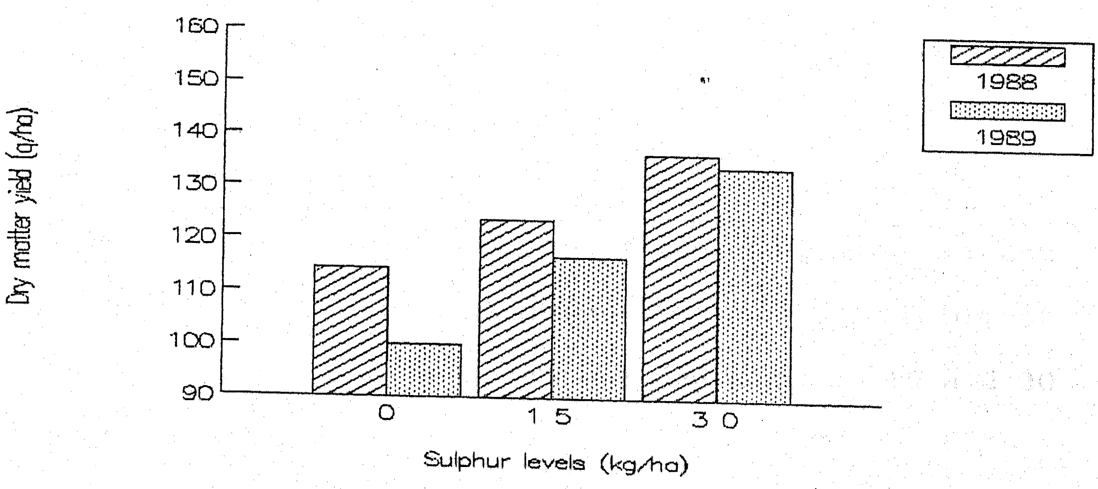


FIG 11: DRY MATTER YIELD (q/ha)







1988 (367.4 q/ha) as compared to 1989 (334.2 q/ha). Sorghum varieties differed significantly in green forage yields in both the years of investigation. Variety HC-136 producing 443.9 q/ha in 1988 and 371.6 q/ha in 1989 gave a significant lead over HD-2 and PC-6 which in turn were statistically at par between themselves. On the average over the years variety HC-136 registered the highest yield of 407.7 q/ha followed by HD-2 (324.1 q/ha) and PC-6 (317.6 q/ha).

The effect of nitrogen nutrition on green forage yield was found to be statistically significant in both the years. Application of increasing doses of nitrogen from 30 to 90 kg N/ha caused significant increase in forage yield with the result that 90 kg N/ha yielded significantly higher green forage of 416.8 q/ha in 1988 and 370.2 q/ha in 1989. The data on green forage yield averaged over two yedars showed that application of 30, 60 and 90 kg N/ha produced green forage yields of 308.4, 347.6 and 390.5 q/ha, respectively.

Sulphur nutrition increased the green forage yield significantly. Application of 15 and 30 kg S/ha improved green forage significantly over control treatment. The differences between 15 and 30 kg S/ha were also significant in both the years. On an average, the forage yields of 311.6, 350.3 and 387.5 q/ha were obtained with 0, 15 and 30 kg S/ha, respectively.

The data on significant V x N interaction for green forage yield in both the years presented in Table 12 and 13 indicated that variety HC-136 fertilized with 90 kg N/ha significantly out yielded the other combinations. Variety HC-136 receiving 60 kg N/ha produced statistically higher green forage yield over 30 kg N/ha in 1989 but not in 1988.

The significant V x S interaction in 1989 (Table 13) revealed that variety HC-136 fertilized with 30 kg S/ha produced significantly higher green forage yield over other combinations of varieties and sulphur levels. The green forage yield of variety HC-136 at 15 kg S/ha was statistically at par with that of variety HD-2 at 30 kg S/ha.

The N x S interaction for both green and dry matter yields in 1989 indicated that 90 kg N and 30 kg S/ha produced significantly higher green forage yield as compared to other fertilizer schedules. The next best fertilizer combination appeared to be 60 kg N and 15 kg S/ha.

Dry matter yield: The average dry matter yield was 125.0 q/ha in 1988 against 116.6 q/ha in 1989. Variety HC-136 produced significantly higher dry matter yield over PC-6 and HD-2. The differences in dry matter yields of PC-6 and HD-2 were not significant in both the years. In 1989, these two varieties yielded practically similiar dry matter. Average data on dry matter, however, indicated that the sorghum varieties may be reckoned as HC-136 $>$ PC-6 $>$ HD-2.

Table 12. Effect of V x N interaction on green forage yield (q/ha) in 1988.

Nitrogen (kg/ha)	Varieties		
	PC-6	HD-2	HC-136
30	283.3	294.0	385.7
60	330.7	332.4	424.8
90	362.4	366.5	529.0

SEm ± 13.82

CD at 5% 40.5

Table 13. Effect of V x N, V x S and N x S interactions on green forage yield (q/ha) in 1989

Nitrogen(kg/ha)	V x N Varieties			Sulphur(kg/ha)	V x S Varieties			N x S Nitrogen(kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	279.1	268.2	318.2	0	293.2	272.4	327.4	368.2	295.7	329.0
60	308.2	327.4	369.0	15	306.5	322.4	376.5	289.1	401.5	381.5
90	348.2	362.4	427.3	30	335.7	364.0	410.7	308.2	374.9	427.3

SEm ± 6.18

CD at 5% 18.1

The effect of nitrogen nutrition on dry matter production was significant in both the years. The increasing doses of nitrogen from 30 to 90 kg/ha increased the dry matter yield progressively and the successive differences were statistically significant. On an average, application of 30, 60 and 90 kg N/ha produced dry matter yields of 102.9, 121.7 and 139.4 q/ha, respectively indicating constant rate of dry matter accumulation with successive increase of nitrogen by 30 kg/ha.

Sulphur nutrition exercised significant effect on dry matter production in both the years of experimentation. Application of 30 kg S/ha yielded significantly higher dry matter over 0 and 15 kg S/ha. Use of 15 kg S/ha, however, accumulated significantly higehr dry matter over no sulphur treatment only in 1989. The difference in 1988 was statistically at par. On an average application of 15 and 30 kg S/ha produced additional dry matter of 13.0 and 28.1 q/ha over control treatment.

The data on significant interactions V x N, V x S and N x S are presented in Table 14. The perusal of the data revealed that variety HC-136 receiving 90 kg N/ha significantly out yielded (154.9 q/ha) other combinations. The dry matter yield of HC-136 at 60 kg N/ha was statistically at par with that of HD-2 fertilized with 90 kg N/ha.

Table 14. Effect of V x N, V x S and N x S interactions on dry matter yield (q/ha) in 1989

Nitrogen(kg/ha)	V x N Varieties			Sulphur(kg/ha)	V x S Varieties			N x S Nitrogen (kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	95.8	86.6	108.3	0	100.0	89.1	111.6	88.3	100.8	111.6
60	108.3	114.1	132.4	15	107.5	109.1	133.3	95.8	118.3	136.6
90	125.0	128.3	154.9	30	121.6	130.8	150.8	107.5	135.8	159.9

SEm$\pm$ 2.86

CD at 5% 8.4

The data on significant V x S interaction are presented in Table 14. Significantly highest dry matter yield of 150.8 q/ha was obtained when variety HC-136 was fertilized with 30 kg S/ha. The dry matter production of this variety with 15 kg S/ha was statistically at par with that of HD-2 receiving 30 kg S/ha.

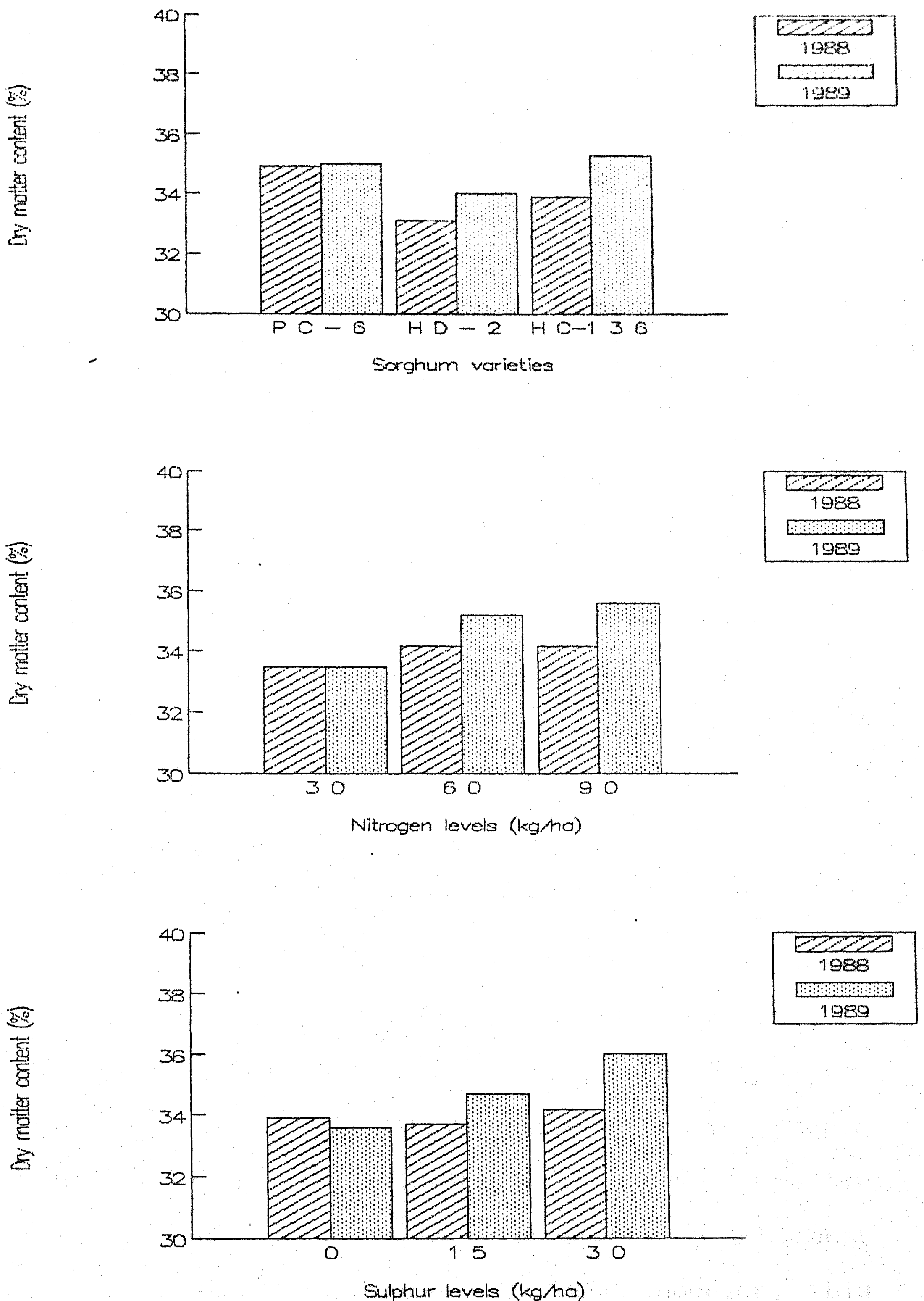
The significant N x S interaction revealed that sorghum crop fertilized with 90 kg N and 30 kg S/ha produced significantly highest dry matter yield of 159.9 q/ha. The fertilizer combinations of 90 kg N plus 15 kg S/ha and 60 kg N plus 30 kg S/ha, however, produced statistically similar dry matter yields.

Dry matter content: The perusal of the data on dry matter content (Table 15, Fig. 12) showed that the crop exhibited average dry matter of 34.0 per cent in 1988 and 34.8 per cent in 1989. In 1988, though the highest dry matter content of 34.9 per cent was observed with variety PC-6 and lowest with HD-2 (33.1%) but the differences did not reach the level of significance. In 1989 the maximum dry matter of 35.3 per cent was recorded with variety HC-136 which did not differ from PC-6. Both of them, however, accumulated significantly higher dry matter content than HD-2. On an average the dry matter contents of PC-6, HD-2 and HC-136 were 35.0, 33.6 and 34.6 per cent, respectively.

Table 15. Dry matter content (%)

Treatments	1988	1989
Sorghum varieties		
PC-6	34.9	35.0
HD-2	33.1	34.0
HC-136	33.9	35.3
SEm ±	0.67	0.26
CD at 5%	NS	0.8
Nitrogen levels (kg/ha)		
30	33.5	33.5
60	34.2	35.2
90	34.2	35.6
SEm ±	0.67	0.26
CD at 5%	NS	0.8
Sulphur levels (kg/ha)		
0	33.9	33.6
15	33.7	34.7
30	34.2	36.0
SEm ±	0.67	0.26
CD at 5%	NS	0.8
General Mean	34.0	34.8

FIG 12: DRY MATTER CONTENT (%)



The effect of nitrogen nutrition on dry matter content was not significant in 1988, whereas in 1989 application of 60 and 90 kg N/ha produced significantly higher dry matter content over 30 kg N/ha. On the basis of the average data it was observed that the application of 60 and 90 kg N/ha gave practically similar but comparatively higher dry matter content than 30 kg N/ha.

In line with the nitrogen effect, sulphur application also did not exercise significant effect on dry matter content in 1988. However, in 1989 increasing doses of sulphur from 0 to 30 kg S/ha increased the dry matter content and the successive differences were significant. Thus, on an average, 15 and 30 kg S/ha gave dry matter content of 34.2 and 35.1 per cent, respectively against 33.8 per cent for control treatment.

Forage productivity per day:

The data on green and dry matter productivity/ha/day have been presented in Table 16 and in Fig. 13 and 14.

The perusal of the data indicated that average green matter productivity was 4.33 q/ha/day in 1988 against 3.99 q/ha/day in 1989. The corresponding values for dry matter productivity were 1.42 and 1.50 q/ha/day. The sorghum varieties differed significantly in green matter productivity and HD-2 gave consistantly highest productivity in both the years. In 1988, however, this

Table 16. Green forage and dry matter productivity (q/ha/day)

Treatments	Green fodder productivity (q/ha/day)		Dry matter productivity (q/ha/day)	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	3.83	3.67	1.25	1.49
HD-2	4.75	4.58	1.58	1.52
HC-136	4.50	3.75	1.33	1.51
SEm±	0.099	0.042	0.025	0.042
CD at 5%	0.25	0.17	0.08	0.17
Nitrogen levels (kg/ha)				
30	3.83	3.41	1.17	1.24
60	4.33	4.00	1.42	1.50
90	4.91	4.50	1.58	1.67
SEm ±	0.099	0.042	0.025	0.042
CD at 5%	0.25	0.17	0.08	0.17
Sulphur levels (kg/ha)				
0	4.00	3.50	1.33	1.33
15	4.33	4.00	1.42	1.50
30	4.66	4.41	1.58	1.58
SEm ±	0.099	0.042	0.025	0.042
CD at 5%	0.25	0.17	0.08	0.17
General Mean	4.33	3.99	1.42	1.50

FIG 13: GREEN FORAGE PRODUCTIVITY

(q/ha/day)

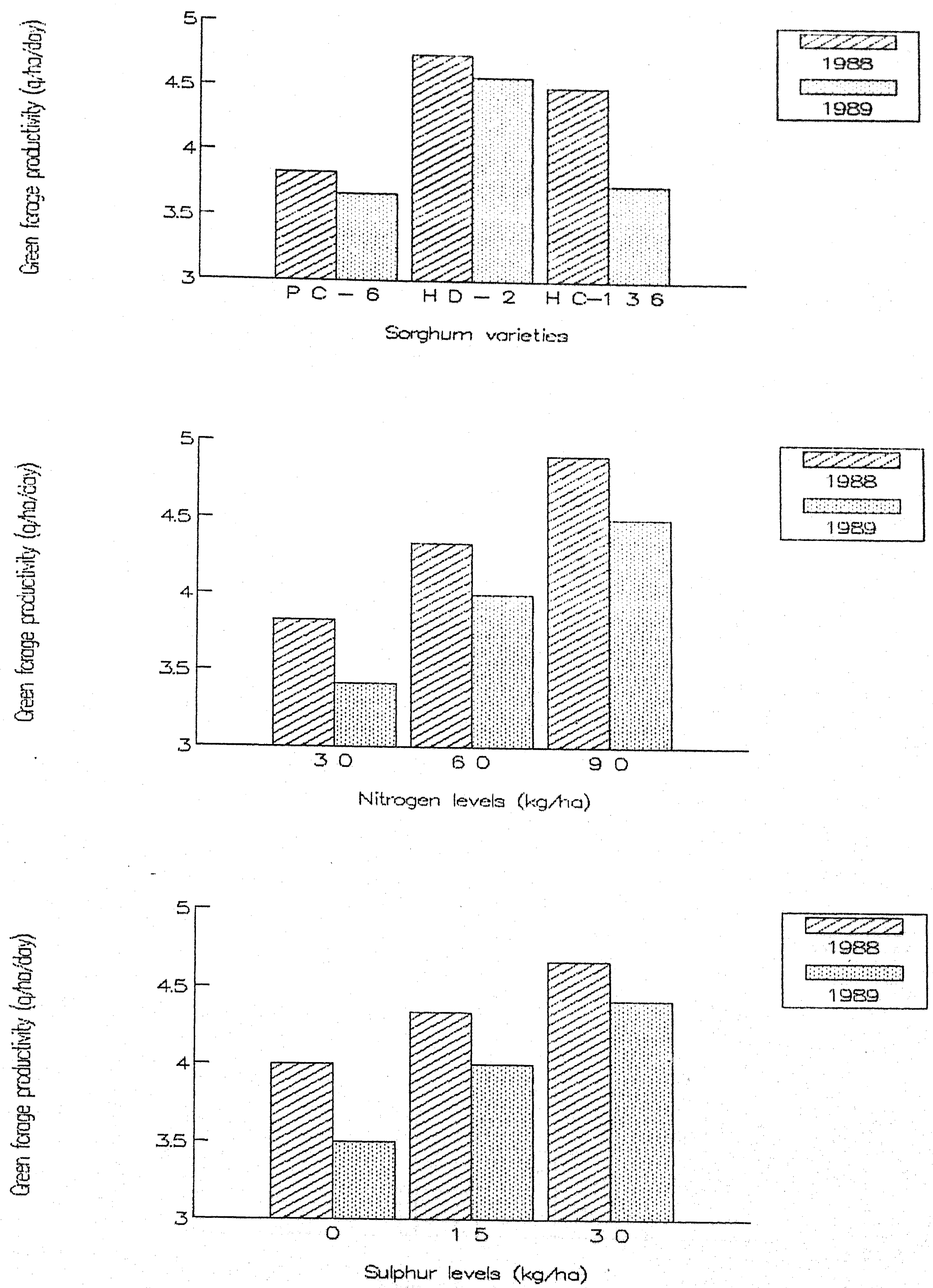
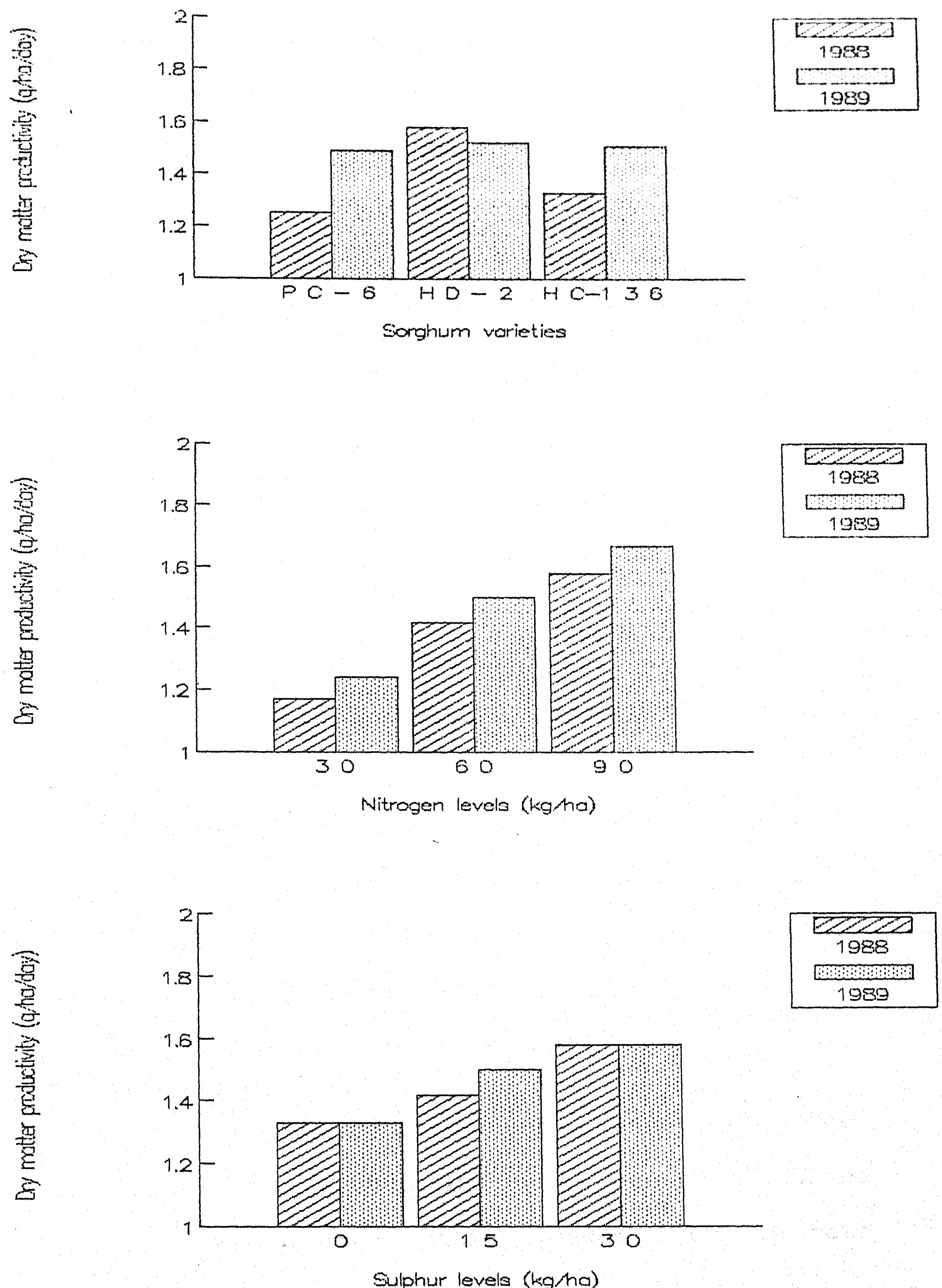


FIG 14: DRY MATTER PRODUCTIVITY

(q/ha/day)



variety was at par with HC-136 but significantly superior to PC-6. In 1989, PC-6 and HC-136 did not differ between themselves but gave significantly lower productivity than HD-2. On the basis of the average data over two years, the productivity of sorghum varieties could be rated as HD-2 > HC-136 > PC-6. In terms of dry matter productivity also HD-2 proved significantly superior over PC-6 and HC-136 which in turn were at par between themselves in 1988. In 1989, HD-2 did not differ significantly from HC-136 which of course was at par with PC-6.

Increasing doses of nitrogen from 30 to 90 kg N/ha progressively increased the green matter productivity and the successive differences were statistically significant in both the years. Application of 90 kg N/ha gave highest green forage productivity of 4.91 q/ha/day in 1988 and 4.50 q/ha/day in 1989. The increasing doses of nitrogen increased the dry matter productivity in both the years. In 1988, the successive differences between 60 and 30 and between 90 and 60 were significant. In 1989, 60 and 90 kg N/ha were at par between themselves but proved significantly superior over 30 kg N/ha.

The sulphur nutrition also exercised significant effect on forage productivity of sorghum. Increasing doses of sulphur from 0 to 15 and 15 to 30 kg S/ha caused significant increase in green matter productivity in both

the years. There was a constant rate of increase in green matter productivity with increasing levels of sulphur. In terms of dry matter productivity, however, the gains due to 15 and 30 kg S/ha over 0 and 15 kg S/ha were at par in both the years.

The interactions, V x N, V x S and N x S exercised significant effect on dry matter productivity in 1988 (Table 17) and on green matter productivity in 1989 (Table 18). Variety HD-2 at 90 kg N/ha and also at 30 kg S/ha gave significantly highest green forage productivity of 5.16 q/ha/day (1.83 q dry matter) as compared to other V x N and V x S combinations. The fertilizer schedule consisting of 90 kg N and 30 kg S/ha registered the highest green matter productivity of 5.08 q/ha/day (1.92 q dry matter/ha/day).

Forage quality:

Crude protein (CP): The data on crude protein content at various stages of growth for two years have been presented in Table 19 and 20 and depicted in Fig. 15, 16 and 17. The perusal of the data indicated that in 1988, the crude protein content decreased from 18.63 per cent at 25 days after sowing (DAS) to 5.23 per cent at harvest, whereas in 1989 the drop was from 16.44 to 5.46 per cent.

In 1988 (Table 19) at 25 DAS variety HD-2 recorded highest crude protein content of 19.99 per cent which was

Table 17. Effect of V x N, V x S and N x S interactions on dry matter productivity (q/ha/day) in 1988

Nitrogen(kg/ha)	V x N Varieties			Sulphur(kg/ha)	V x S Varieties			N x S Nitrogen(kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	1.17	1.25	1.08	0	1.17	1.25	1.08	1.00	1.17	1.33
60	1.25	1.67	1.33	15	1.25	1.58	1.33	1.17	1.42	1.58
90	1.50	1.83	1.58	30	1.42	1.83	1.50	1.25	1.67	1.92

SEm ± 0.033

CD at 5% 0.08

Table 18. Effect of V x N, V x S and N x S interactions on green forage productivity (q/ha/day) in 1989

Nitrogen(kg/ha)	V x N Varieties			Sulphur(kg/ha)	V x S Varieties			N x S Nitrogen(kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	3.25	3.83	3.13	0	3.42	3.92	3.25	3.17	3.50	3.92
60	3.67	4.66	3.67	15	3.58	4.58	3.75	3.42	3.50	4.58
90	4.08	5.16	4.25	30	3.92	5.16	4.08	3.67	4.50	5.08

SEm ± 0.075

CD at 5% 0.25

Table 19. Crude protein content (%) at different crop growth stages in 1988

Treatments	Days after sowing					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	16.24	12.15	9.10	6.20	4.80*	
HD-2	19.99	12.25	8.01	5.46*	-	
HC-136	19.67	12.95	9.45	5.67	6.36	5.41*
SEm $\pm$	0.16	0.094	0.10	0.18	-	0.019
CD at 5%	0.54	0.32	0.35	NS	-	0.07
Nitrogen levels(kg/ha)						
30	17.95	11.80	7.64	4.93	5.34	4.83
60	18.70	12.43	8.76	5.76	5.48	5.25
90	19.25	13.15	10.76	6.64	5.92	5.60
SEm $\pm$	0.16	0.094	0.10	0.18	-	0.019
CD at 5%	0.54	0.32	0.35	0.62	-	0.07
Sulphur levels (kg/ha)						
0	17.35	11.60	7.76	4.86	4.74	4.44
15	18.41	12.39	8.67	5.73	5.79	5.25
30	20.14	13.38	10.15	6.74	6.22	5.60
SEm $\pm$	0.16	0.094	0.10	0.18	-	0.019
CD at 5%	0.54	0.32	0.35	0.62	-	0.07
General Mean	18.63	12.46	8.86	5.78	5.58	5.23

* Harvesting stage

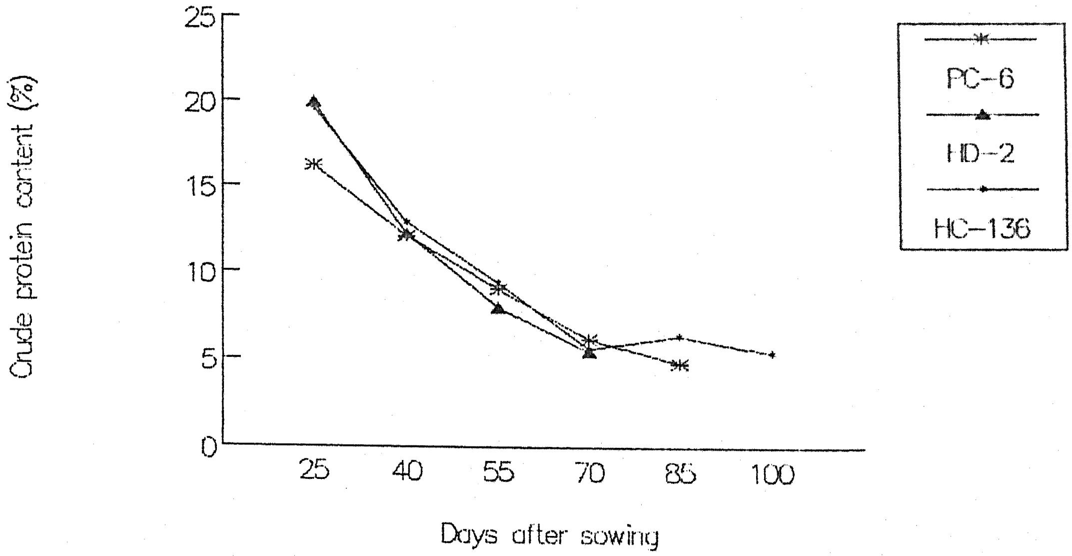
Table 20. Crude protein content (%) at different crop growth stages in 1989

Treatments	Days after sowing					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	16.38	12.81	7.99	7.03	5.12*	-
HD-2	17.00	13.28	8.60	6.44*	-	-
HC-136	15.93	12.55	8.40	6.69	5.14	4.81 *
SEm ±	0.18	0.102	0.23	0.08	-	0.09
CD at 5%	0.60	0.35	NS	0.26	-	0.31
Nitrogen levels(kg/ha)						
30	15.07	12.18	7.35	6.11	4.65	4.98
60	16.13	12.82	8.40	6.66	4.86	5.27
90	18.12	13.55	9.26	7.40	5.89	6.12
SEm ±	0.18	0.102	0.23	0.08	-	0.09
CD at 5%	0.60	0.35	0.74	0.26	-	0.31
Sulphur levels(kg/ha)						
0	14.75	12.16	7.20	6.06	4.65	4.90
15	16.44	12.95	8.41	6.58	5.13	5.34
30	18.14	13.54	9.40	7.52	5.60	6.13
SEm ±	0.18	0.102	0.23	0.08	-	0.09
CD at 5%	0.60	0.35	0.74	0.26	-	0.31
General Mean	16.49	12.88	8.33	6.72	5.13	5.46

* At harvesting stage

FIG 15: CRUDE PROTEIN CONTENT (%)

SORGHUM VARIETIES , 1988



1989

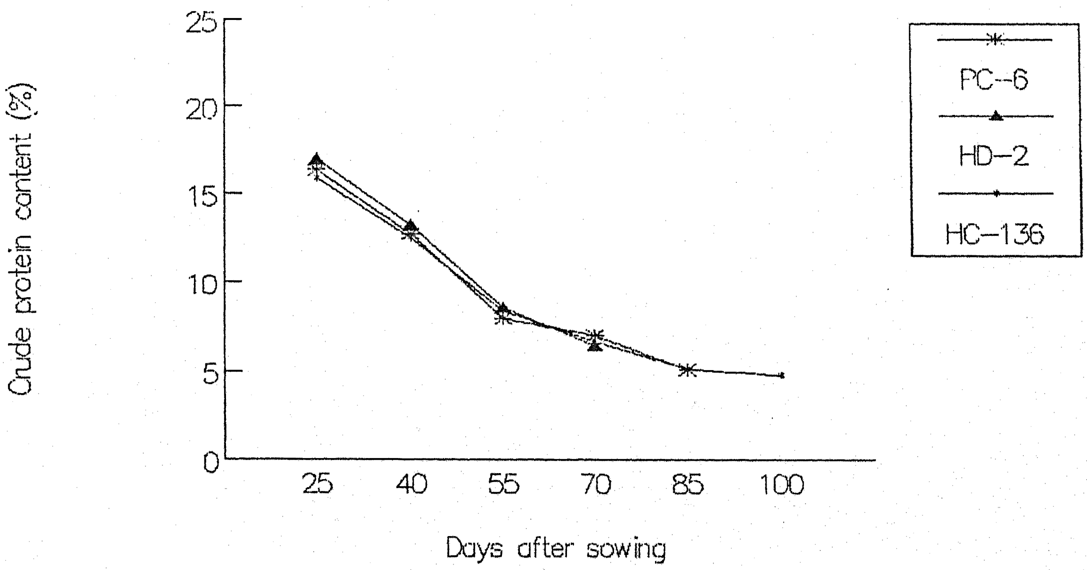
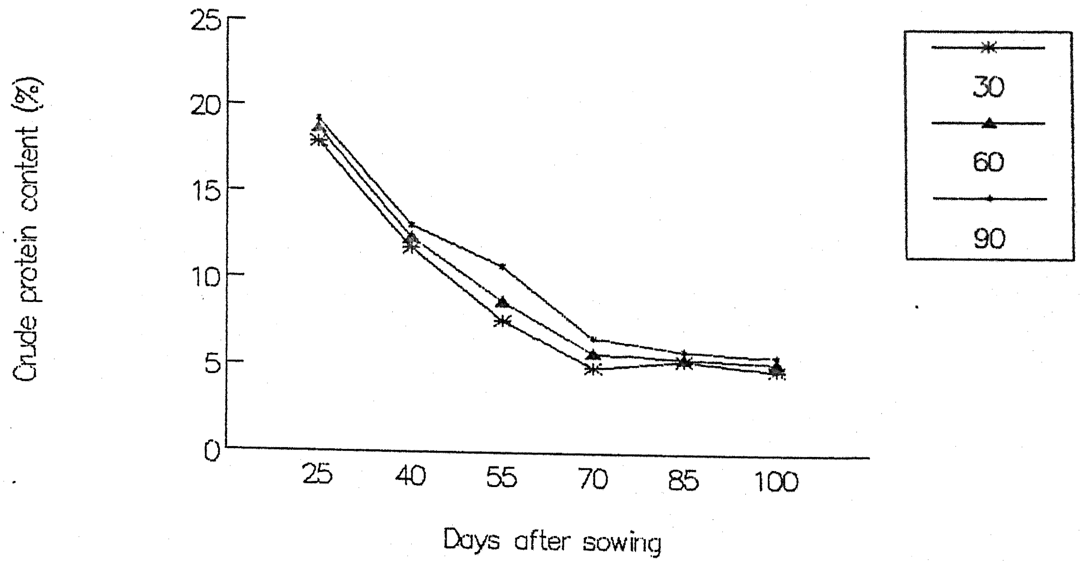


FIG 16: CRUDE PROTEIN CONTENT (%)

NITROGEN LEVELS (kg/ha) , 1988



1989

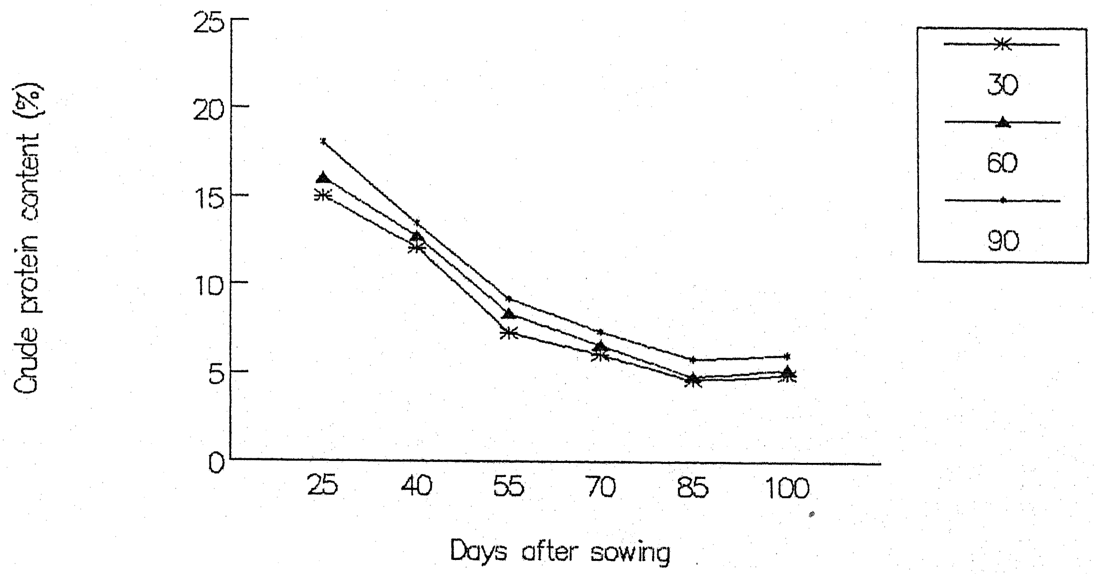
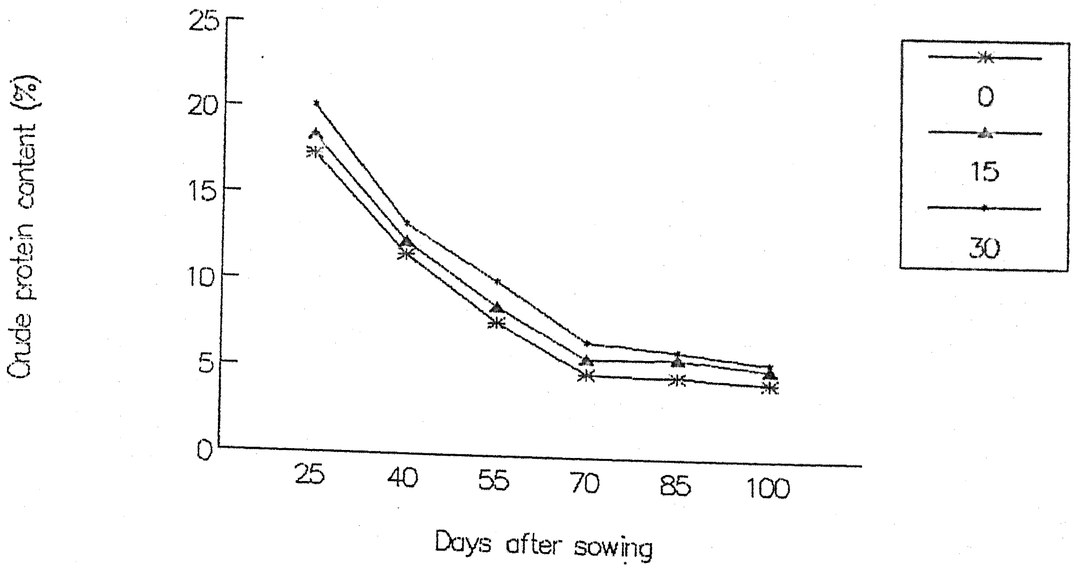
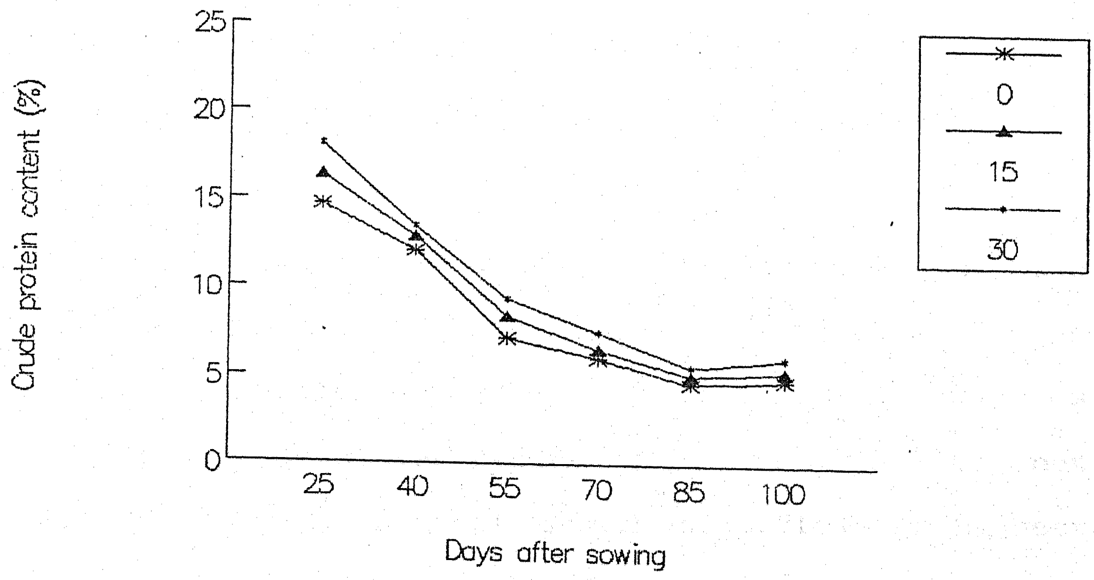


FIG 17: CRUDE PROTEIN CONTENT (%)

SULPHUR LEVELS (kg/ha) , 1988



1989



at par with HC-136 but significantly superior to PC-6. At 40 DAS, however, HC-136 registered significantly higher crude protein of 12.95 per cent. Varieties HD-2 and PC-6 exhibited statistically similar crude protein content. At 55 DAS, HC-136 and PC-6 gave significantly higher crude protein content than HD-2 but were at par between themselves. At 70 days of growth coinciding with harvesting stage of HD-2, the variation in crude protein content of different sorghum varieties was not statistically significant. At 85 days of growth (harvesting stage for PC-6) variety HC-136 gave 6.35 per cent crude protein against 4.80 per cent in PC-6.

When the data on crude protein content of all the varieties at their respective harvesting stages were compared, it was observed that variety HD-2 recorded highest crude protein content of 5.46 per cent, but did not differ significantly with HC-136 with crude protein content of 5.41 per cent. These two varieties were, however, significantly superior to PC-6 (4.80%).

In 1989 (Table 20) variety HD-2 maintained an edge over HC-136 and PC-6 in crude protein content upto 55 days of growth. However, the protein content of HD-2 was significantly higher over others at 25 and 40 DAS but not at 55 DAS. At 70 days of growth significantly highest crude protein content was found in PC-6 as compared to HC-136 and HD-2 which were at par between themselves. At

85 days PC-6 maintained its superiority over HC-136 in protein content. At harvesting stage variety HD-2 registered significantly highest crude protein content of 6.44 per cent over PC-6 and HC-136 which did not differ between themselves.

Nitrogen nutrition exercised positive effect in increasing the protein content at all the stages of growth in both the years. At 25 DAS, application of 90 kg N/ha gave significantly highest crude protein content of 19.25 per cent as compared to 30 and 60 kg N/ha which were at par between themselves in 1988, but different significantly in 1989. At 40, 55 and 70 days of crop growth the application of 30, 60 and 50 kg N/ha increased the crude protein content significantly from each other during both the years. Similar trend was maintained at 85 days of growth for remaining varieties. At harvest, the application of increasing doses of nitrogen from 30 to 90 kg/ha progressively increased the protein content from 4.83 per cent to 5.60 per cent and the successive differences were significant in 1989, however, the crop receiving 90 kg N/ha contained significantly higher crude protein of 6.12 per cent over 30 and 60 kg N/ha which were at par between themselves.

The response of sorghum to sulphur nutrition was distinct in terms of crude protein content at various crop growth stages in both the years. The application of

15 kg S/ha showed significantly higher crude protein content over control treatment. Similarly, 30 kg S/ha proved significantly superior over 15 kg S/ha throughout the crop growth period. At harvest also the increasing doses of sulphur from 0 to 30 kg/ha caused significant variation in crude protein content and the successive differences were statistically significant in both the years. The magnitude of response was more when the dose of sulphur was increased from 0 to 15 kg/ha as compared to its increase from 15 to 30 kg/ha in 1988. The reverse trend was, however, observed in the year 1989.

In 1988, the interaction between varieties and sulphur levels at 25 DAS (Table 21) was significant with the result that variety HD-2 fertilized with 30 kg S/ha recorded significantly highest protein content but it did not differ significantly with its protein content at 15 kg S/ha. Variety HC-136 at 30 kg S/ha also recorded similar protein content. The significant V x N interaction at 40 DAS (Table 21) revealed that HD-2 receiving 90 kg N/ha exhibited significantly higher protein content as compared to other combinations except HC-136 fertilized with 60 and 90 kg N/ha.

The data on V x N and N x S interactions (Table 22) revealed that at 55 DAS varieties interacted significantly with nitrogen levels with the result that varieties PC-6 and HC-136 receiving 90 kg N/ha registered significantly

Table 21. Effect of V x S and V x N interactions on crude protein content (%) in 1988

Sulphur (kg/ha)	25 DAS Varieties			Nitrogen(kg/ha)	40 DAS Varieties		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136
0	14.9	18.69	19.05	30	11.30	11.36	12.15
15	15.34	20.11	19.79	60	12.23	11.74	13.19
30	19.08	21.16	20.17	90	12.94	13.69	13.52

SEm $\pm$ 0.270 SEm $\pm$ 0.162

CD at 5% 0.94 CD at 5% 0.56

Table 22. Effect of V x N and N x S interactions on crude protein content (%) at 55 DAS in 1988

Nitrogen(kg/ha)	Varieties			Sulphur(kg/ha)	Nitrogen (kg/ha)		
	PC-6	HD-2	HC-136		30	60	90
30	8.23	6.43	8.25	0	6.58	7.51	9.18
60	8.55	7.91	9.81	15	7.96	8.66	9.38
90	10.52	9.70	10.29	30	8.37	10.11	11.96

SEm ± 0.17C

CD at 5% 0.60

higher protein content as compared to remaining combinations. Similarly, the interaction between nitrogen and sulphur levels indicated that 90 kg N and 30 kg S/ha registered significantly highest protein content over other fertilizer combinations. This was followed by 60 kg N and 30 kg S/ha.

At harvesting stage the interactions V x N, V x S and N x S were found to be significant (Table 23). Variety HD-2 fertilized with 90 kg N or 30 kg S/ha exhibited significantly higher protein content as compared to other respective combinations. Sorghum fertilized with 90 kg N and 30 kg S/ha recorded significantly higher protein content of 6.25 per cent but did not differ statistically from 60 kg N and 30 kg S/ha (6.18%).

In 1989, the interaction V x N was significant at 25 and 40 DAS (Table 24). At 25 DAS variety HC-136 with 90 kg N/ha showed significantly highest protein content but did not differ statistically with varieties HD-2 and PC-6 receiving the same dose of nitrogen. At 40 DAS significantly highest protein content was observed with variety HD-2 receiving 90 kg N/ha. This was, however, at par with the protein content obtained from PC-6 fertilized with 90 kg N/ha.

Table 23. Effect of V x N, V x S and N x S interactions on crude protein content (%) at harvest in 1988

Nitrogen(kg/ha)	Varieties			Sulphur(kg/ha)	Varieties			Nitrogen(kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	4.48	5.01	4.99	0	4.06	4.54	4.72	4.20	4.41	4.71
60	4.88	5.21	5.64	15	4.93	5.60	5.37	4.91	5.15	5.84
90	5.04	6.16	5.60	30	5.41	6.25	6.14	5.37	6.18	6.25

SEm ± 0.033

CD at 5% 0.11

Table 24. Effect of V x N interaction on crude protein content (%) in 1989

Nitrogen (kg/ha)	25 DAS Varieties			40 DAS Varieties		
	PC-6	HD-2	HC-136	PC-6	HD-2	HC-136
30	15.08	16.02	14.11	11.61	12.86	11.99
60	16.28	17.09	15.03	13.22	13.10	12.55
90	17.79	17.90	18.66	13.61	13.91	13.10
SEm ±	0.320			SEm ± 0.176		
CD at 5%	1.03			CD at 5% 0.61		

<u>Water soluble carbohydrates(WSC)</u>: There was a progressive increase in carbohydrate content up to 70 days of plant growth and declined there after. The water soluble carbohydrate content varied from 4.92 per cent at 25 days to 7.85 per cent at 70 days of growth in 1988. The corresponding values in 1989 were 3.07 to 6.12 per cent (Table 25 & 26 and Fig. 18, 19 & 20).

In 1988 (Table 25) variety HC-136 continued to exhibit higher concentration of water soluble carbohydrate as compared to other two varieties. However, it did not differ significantly from HD-2 at 25 and 40 DAS. At subsequent stages the differences in water soluble carbohydrates became more obvious with the result that the differences between HD-2 and PC-6 and between HC-136 and HD-2 were significant.

In 1989 (Table 26) also, variety HC-136 registered higher concentration of water soluble carbohydrates as compared to other varieties upto 55 DAS. At 25 days, sorghum varieties differed significantly from each other with respect to water soluble carbohydrates. At 40 days, however, the differences were not significant. At 55 days again, the differences in the concentration of water soluble carbohydrates between HD-2 and PC-6 and between HC-136 and HD-2 were significant. At 70 days of growth HD-2 coinciding with its harvesting stage recorded significantly higher water soluble carbohydrates content

Table 25. Water soluble carbohydrates content (%) at different crop growth stages in 1988

Treatments	Days after sowing					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	4.01	5.65	4.88	6.16	4.39*	-
HD-2	5.22	6.95	6.81	7.37*	-	-
HC-136	5.53	7.12	7.93	10.00	6.91	8.44*
SEm ±	0.161	0.106	0.078	0.102	-	0.079
CD at 5%	0.56	0.35	0.27	0.33	-	0.26
Nitrogen levels (kg/ha)						
30	4.18	6.02	6.17	5.90	5.27	5.10
60	4.72	6.65	6.57	7.95	5.69	6.53
90	5.86	7.05	6.87	9.69	5.99	8.57
SEm ±	0.161	0.106	0.078	0.102	-	0.079
CD at 5%	0.56	0.35	0.27	0.33	-	0.26
Sulphur levels (kg/ha)						
0	3.53	5.36	5.65	7.23	4.64	6.41
15	5.05	6.65	6.41	7.93	5.54	6.68
30	6.18	7.05	7.55	8.38	6.77	7.11
SEm ±	0.161	0.106	0.078	0.102	-	0.079
CD at 5%	0.56	0.35	0.27	0.33	-	0.26
General Mean	4.92	6.57	6.54	7.85	5.65	6.73

* Harvesting stage

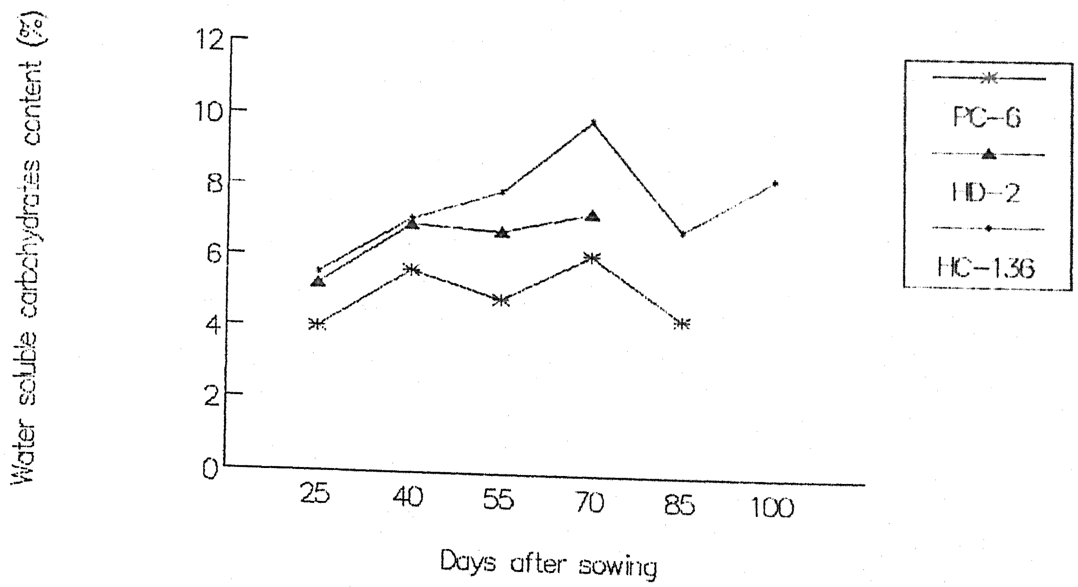
Table 26. Water soluble carbohydrates content (%) at different crop growth stages in 1989

Treatments	Days after sowing					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	2.70	4.79	5.27	4.88	5.92 *	-
HD-2	3.14	5.16	5.58	7.21 *	-	-
HC-136	3.36	5.25	6.26	6.26	6.77	7.26*
SEm ±	0.030	0.150	0.070	0.060	-	0.090
CD at 5%	0.09	NS	0.24	0.19	-	0.31
Nitrogen levels (kg/ha)						
30	2.87	4.04	5.40	5.65	6.15	6.24
60	3.04	5.22	5.72	6.14	6.33	6.76
90	3.29	5.93	5.99	6.56	6.56	7.28
SEm ±	0.030	0,150	0.070	0.060	-	0.090
CD at 5%	0.09	0.49	NS	0.19	-	0.31
Sulphur levels (kg/ha)						
0	2.45	4.59	4.85	5.15	5.70	5.54
15	3.08	5.03	5.51	6.10	6.47	6.67
30	3.67	5.58	6.75	7.09	7.37	8.07
SEm ±	0.030	0.150	0.070	0.060	-	0.090
CD at 5%	0.09	0.49	0.24	0.19	-	0.31
General Mean	3.07	5.07	5.70	6.12	6.35	6.76

* Harvesting stage

FIG 18: WATER SOLUBLE CARBOHYDRATES (%)

SORGHUM VARIETIES , 1988



1989

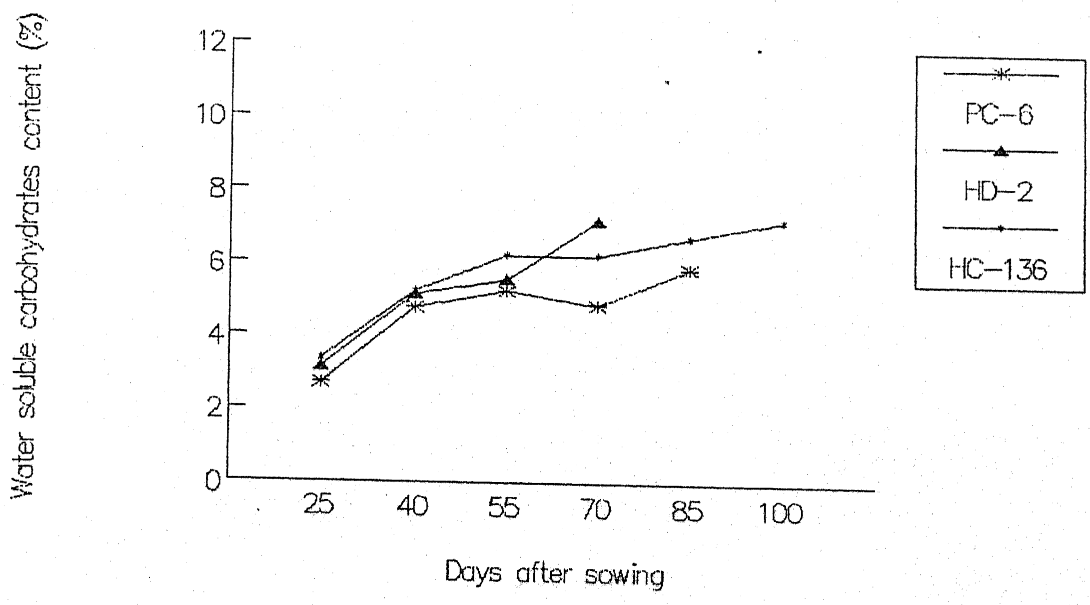
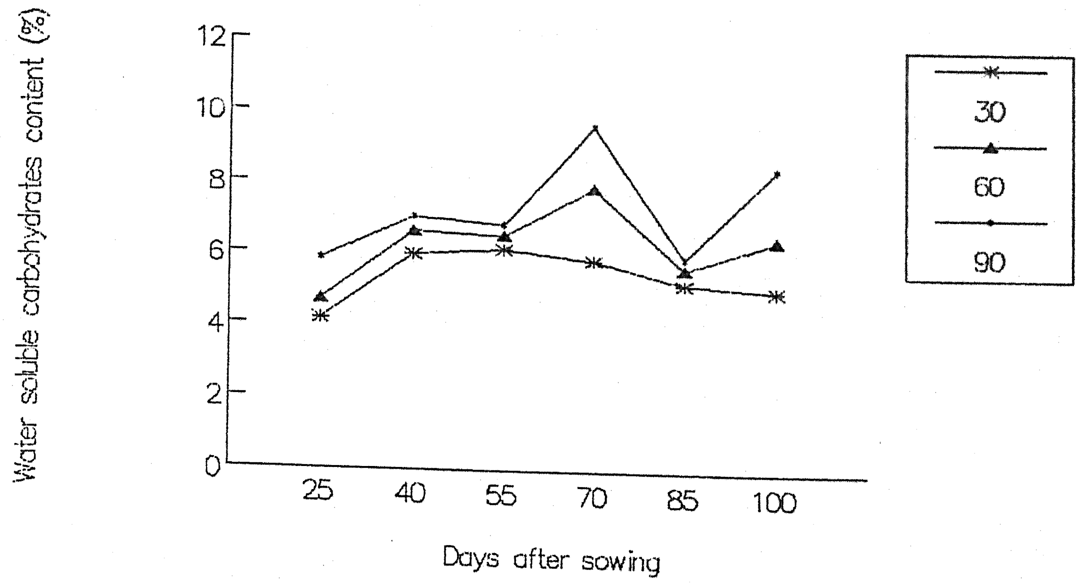


FIG 19: WATER SOLUBLE CARBOHYDRATES (%)

NITROGEN LEVELS (kg/ha) , 1988



1989

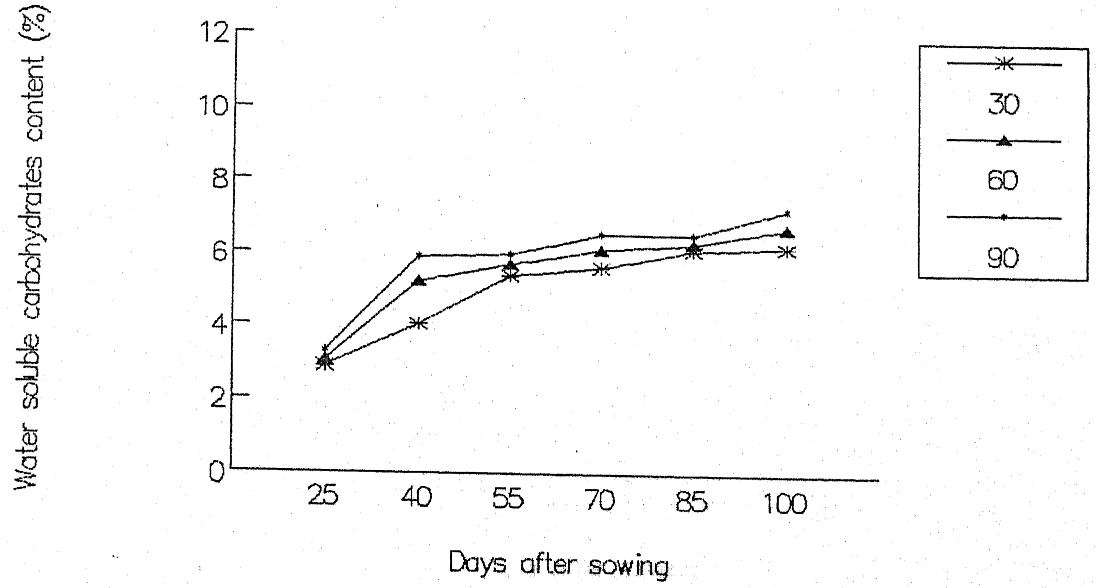
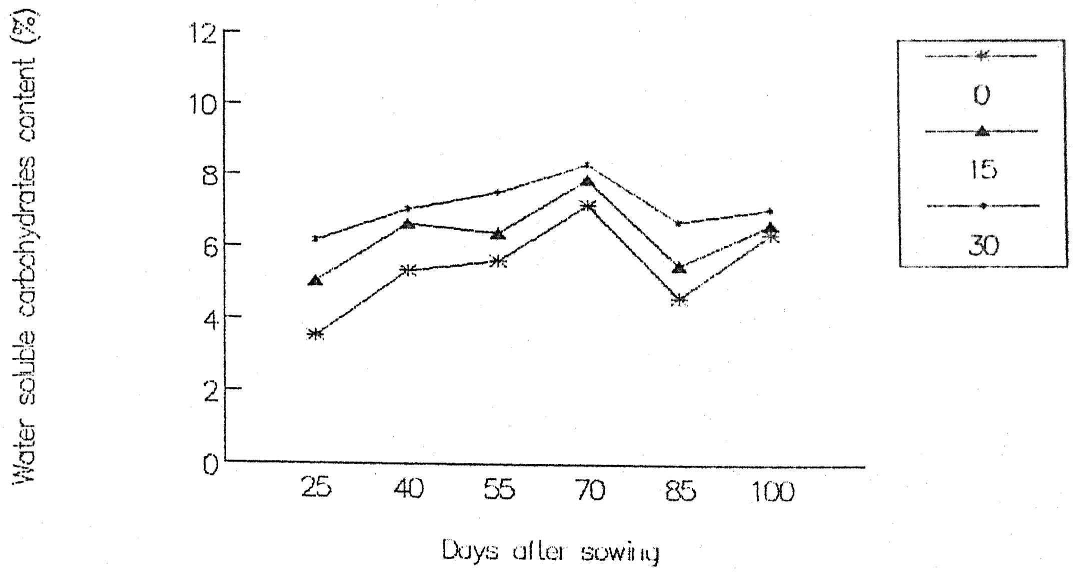
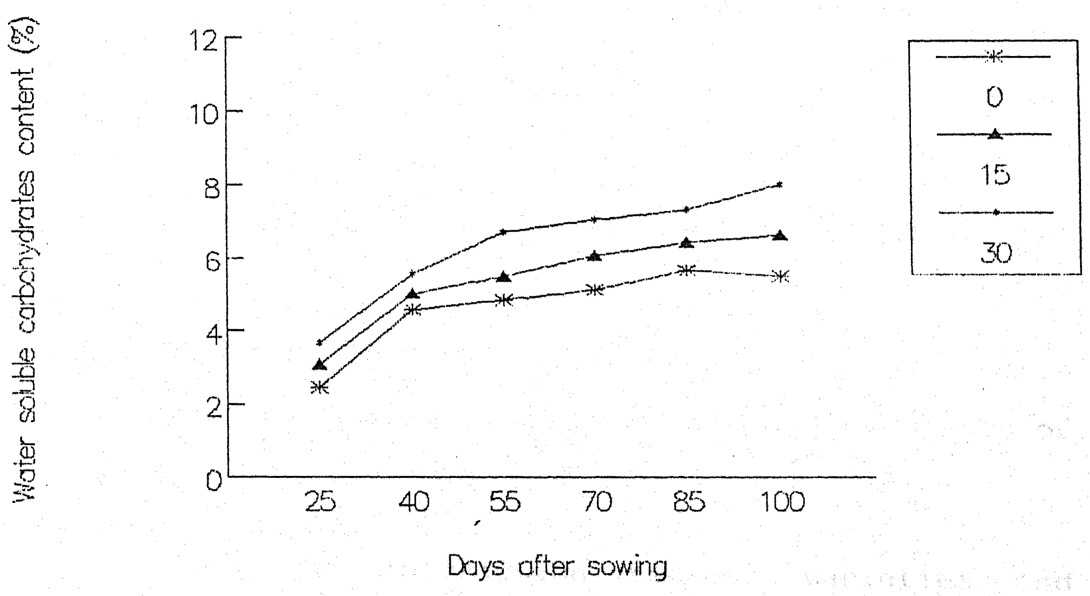


FIG 20: WATER SOLUBLE CARBOHYDRATES (%)

SULPHUR LEVELS (kg/ha) , 1988



1989



over HC-136 and PC-6 which also differed significantly between themselves. At harvest, HC-136 and HD-2 exhibited practically the same (7.21 and 7.25%) WSC but were significantly superior to PC-6 (5.81%).

Nitrogen nutrition enhanced the WSC content at all the stages of crop growth in both the years, however, the effect was more pronounced in 1988. At 25 days of growth significantly highest WSC was observed with 90 kg N/ha as compared to 30 and 60 kg N/ha which were statistically at par between themselves. From 40 days till harvest, however, the successive differences in WSC at increasing levels of nitrogen were significant and the highest concentration was recorded at 90 kg N/ha.

In 1989, the increasing doses of nitrogen from 30 to 90 kg N/ha increased the water soluble carbohydrates and the successive differences were significant at all the stages of crop growth except 55 days.

The effect of sulphur nutrition on water soluble carbohydrates content of sorghum was significant at all the growth stages in both the years of experimentation. The water soluble carbohydrates content at 0, 15 and 30 kg S/ha differed significantly with each other at all the stages of crop growth.

In 1988, the interaction between varieties and sulphur was significant at 55 days of growth and also at

harvest (Table 27). At both these stages variety HC-136 receiving 30 kg S/ha gave significantly higher WSC content followed by HD-2 fertilized with the same dose of sulphur.

In 1989, the varieties and nitrogen levels interacted significantly (Table 28) with the result that variety HC-136 fertilized with 90 kg N/ha recorded significantly higher WSC content (3.71%) followed by HD-2 (3.24%) receiving the same dose of nitrogen.

The interaction between varieties and sulphur levels was found to be significant at 25, 55 and 70 days of crop growth (Table 28 & 29). Variety HC-136 at 30 kg S/ha exhibited highest WSC content at 25 days (4.19%) and at 55 days (7.37%). This was followed by HD-2 with 30 kg S/ha at these stages. However, at 70 days of growth variety HD-2 surpassed remaining varieties in accumulating significantly higher water soluble carbohydrates content of 8.65 per cent. The next best combination was HD-2 with 15 kg S/ha (7.13%).

The interaction between nitrogen and sulphur levels significantly influenced the WSC content at 25 and 70 days of growth. The application of 90 kg N and 30 kg S/ha resulted in higher WSC content followed by 60 kg N and 30 kg S/ha at both the stages (Table 28 & 29).

Table 27. Effect of V x S interaction on water soluble carbohydrates contents (%) in 1988.

Sulphur (kg/ha)	55 DAS Varieties			At harvest Varieties		
	PC-6	HD-2	HC-136	PC-6	HD-2	HC-136
0	4.15	5.72	7.09	3.41	5.20	6.7
15	4.95	6.81	7.47	4.13	7.47	7.98
30	5.54	7.90	9.22	5.63	9.44	10.64

	55 DAS		At harvest
SEm ±	0.135	SEm ±	0.137
CD at 5%	0.44	CD at 5%	0.45

Table 28. Effect of V x N, V x S and N x S interactions on water soluble carbohydrates content (%) at 25 DAS in 1989.

Nitrogen (kg/ha)	Varieties			Sulphur (kg/ha)	Varieties			Nitrogen(kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	2.50	3.06	3.07	0	2.33	2.41	2.62	2.24	2.48	2.64
60	2.69	3.13	3.31	15	2.68	3.29	3.27	2.97	3.08	3.19
90	2.92	3.24	3.71	30	3.10	3.72	4.19	3.41	3.57	4.03

SEm ± 0.058

CD at 5% 0.19

Table 29. Effect of V x S and N x S interactions on water soluble carbohydrates content (%) in 1989.

Sulphur (kg/ha)	55 DAS Varieties			70 DAS Varieties			70 DAS Nitrogen (kg/ha)		
	PC-6	HD-2	HC-136	PC-6	HD-2	HC-136	30	60	90
0	4.53	4.46	5.55	4.08	5.84	5.56	4.62	5.32	5.51
15	4.96	5.73	5.84	4.87	7.13	6.30	5.95	6.18	6.27
30	6.30	6.57	7.37	5.69	8.65	6.95	6.48	6.91	7.90
SEm ±	0.129			0.100			0.100		
CD at 5%	0.42			0.33			0.33		

<u>Hydrocyanic acid (HCN)</u>: The data on HCN content at different stages of growth for two crop seasons have been presented in Table 30 (a & b) and 31 (a & b) and depicted in Fig. 21, 22 & 23.

The perusal of the data revealed that the average HCN content at 25, 40, 55, 70, 85 and 100 DAS was 401.9, 203.6, 145.0, 45.9, 25.3 and 29.7 ppm, respectively in 1988. The corresponding values in 1989 were 501.2, 226.1, 135.6, 47.0, 19.3 and 36.9 ppm. These observations indicate that the HCN content decreased with advanced stages of crop growth. The reduction was maximum beyond 55 days of growth.

In 1988, variety HD-2 exhibited higher HCN content than HC-136 and PC-6 at all the stages of growth. At 25 and 40 DAS variety PC-6 exhibited significantly lowest HCN content as compared to HC-136 and HD-2. The difference in HCN content of HC-136 and HD-2 was significant at 25 DAS but not at 40 DAS. From 55 DAS till harvest, variety HC-136 continued to exhibit lowest HCN content. At 85 DAS its HCN content was significantly lower than PC-6 and HD-2 which did not differ significantly between themselves. At 70 DAS, however, the HCN content of HC-136 and PC-6 was at par but significantly lower than HD-2. Variety PC-6 at its harvesting stage (85 DAS) gave HCN content of 19.8 ppm against 30.9 ppm for variety HC-136.

Table 30 (a). Hydrocyanic acid content (ppm) at different crop growth stages in 1988.

Treatments	DAS					
	25	40	55	70	85	100
<u>Sorghum varieties</u>						
PC-6	327.3	171.0	157.0	33.9	19.8*	-
HD-2	504.3	235.9	165.3	68.1*	-	-
HC-136	374.1	223.0	112.8	35.8	30.9	1.3*
<u>Nitrogen levels</u> (kg/ha)						
30	358.3	188.1	115.7	24.1	14.8	13.7
60	414.3	209.2	149.8	50.1	24.0	31.8
90	433.1	232.6	169.7	63.6	37.2	43.8
<u>Sulphur levels</u> (kg/ha)						
0	486.8	263.2	180.3	71.7	41.0	44.2
15	412.8	209.3	145.0	44.8	24.3	30.7
30	306.2	157.3	109.8	21.3	10.7	14.3
General Mean	401.9	203.0	145.0	45.9	25.3	29.7

*Harvesting stage

Table 30 (b). Hydrocyanic acid content (ppm) at different crop growth stages in 1988 (Transformed values)

Treatments	DAS 25	40	55	70	85	100
Sorghum varieties						
PC-6	18.0	13.0	12.5	5.5	4.1*	-
HD-2	29.3	15.3	12.7	7.7*	-	-
HC-136	19.3	14.9	10.5	5.5	-	0.9*
SEm ±	0.09	0.12	0.22	0.11	-	0.37
CD at 5%	0.3	0.4	0.7	0.4	-	1.2
Nitrogen levels (kg/ha)						
30	18.8	13.6	10.6	4.1	-	2.7
60	20.2	14.3	12.2	6.8	-	4.3
90	20.6	15.2	12.9	7.7	-	5.6
SEm ±	0.09	0.12	0.22	0.11	-	0.37
CD at 5%	0.3	0.4	0.7	0.4	-	1.2
Sulphur levels (kg/ha)						
0	22.0	16.2	13.4	8.4	-	5.7
15	20.1	14.4	12.0	6.4	-	4.5
30	17.5	12.5	10.4	3.9	-	2.6
SEm ±	0.09	0.12	0.22	0.11	-	0.37
CD at 5%	0.3	0.4	0.7	0.4	-	1.2
General Mean	19.9	14.4	11.9	6.2	-	4.2

* Harvesting stage

Table 31 (a). Hydrocyanic acid content (ppm) at different crop growth stages in 1989.

Treatments	DAS					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	424.6	159.2	88.9	27.0	19.8*	-
HD-2	615.3	290.9	189.0	79.8*	-	-
HC-136	463.6	228.1	128.8	34.1	38.6	11.0*
Nitrogen levels (kg/ha)						
30	426.1	206.9	112.3	27.2	13.5	19.4
60	500.9	225.3	137.3	45.2	19.2	32.2
90	576.5	246.0	157.0	68.4	27.2	48.9
Sulphur levels (kg/ha)						
0	632.8	264.6	179.7	69.7	32.5	47.9
15	542.0	221.0	131.3	45.6	19.2	32.3
30	328.7	192.7	95.7	25.7	6.2	20.3
General Mean	501.2	226.1	135.6	47.0	19.7	36.9

* Harvesting stage

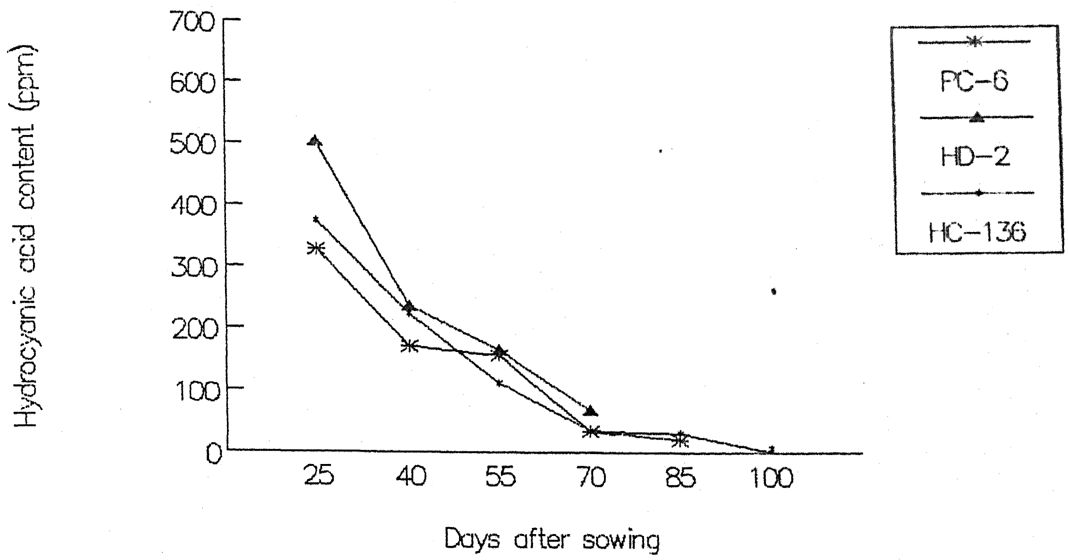
Table 31 (b). Hydrocyanic acid content (ppm) at different crop growth stages in 1989. (Transformed values)

Treatments	DAS					
	25	40	55	70	85	100
Sorghum varieties						
PC-6	20.4	12.6	9.3	4.9	4.1*	-
HD-2	24.5	17.0	13.6	8.7*	-	-
HC-136	21.3	15.0	11.2	5.1	-	0.9*
SEm ±	0.33	0.13	0.25	0.31	-	0.31
CD at 5%	1.1	0.4	0.8	1.0	-	1.0
Nitrogen levels (kg/ha)						
30	20.3	14.3	10.3	4.5	-	3.5
60	22.1	14.9	11.5	6.1	-	4.4
90	23.8	15.5	12.3	8.0	-	5.8
SEm ±	0.33	0.13	0.25	0.31	-	0.31
CD at 5%	1.1	0.4	0.8	1.0	-	1.0
Sulphur levels (kg/ha)						
0	25.0	16.1	13.2	8.1	-	5.8
15	23.1	14.8	11.3	6.4	-	4.6
30	18.0	13.8	9.6	4.1	-	3,2
SEm ±	0.33	0.13	0.25	0.31	-	0.31
CD at 5%	1.1	0.4	0.8	1.0	-	1.0
General Mean	22.1	14.9	11.4	6.2	-	4.5

* Harvesting stage

FIG 21: HYDROCYANIC ACID CONTENT (ppm)

SORGHUM VARIETIES , 1988



1989

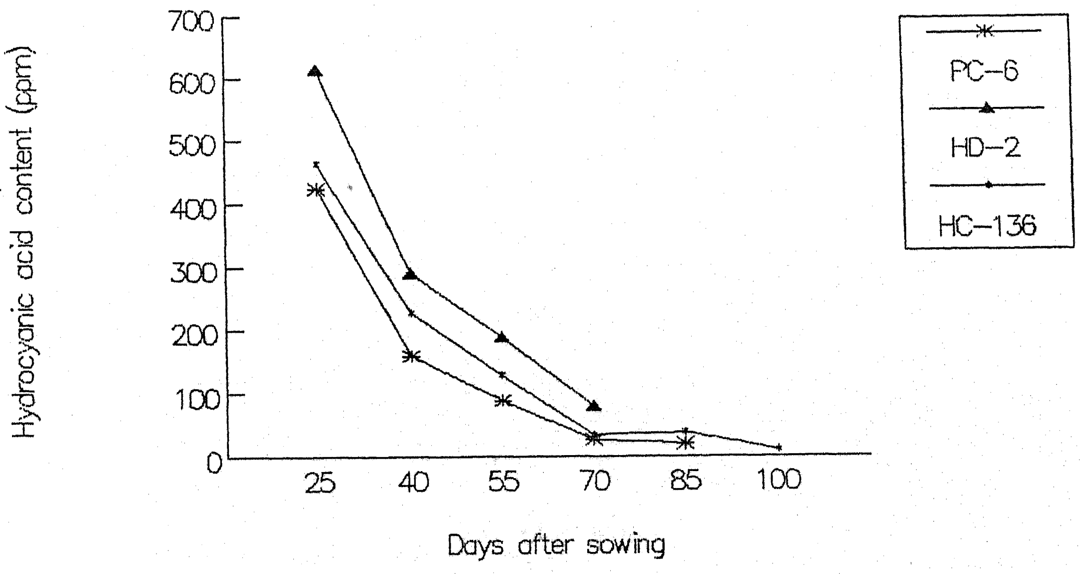
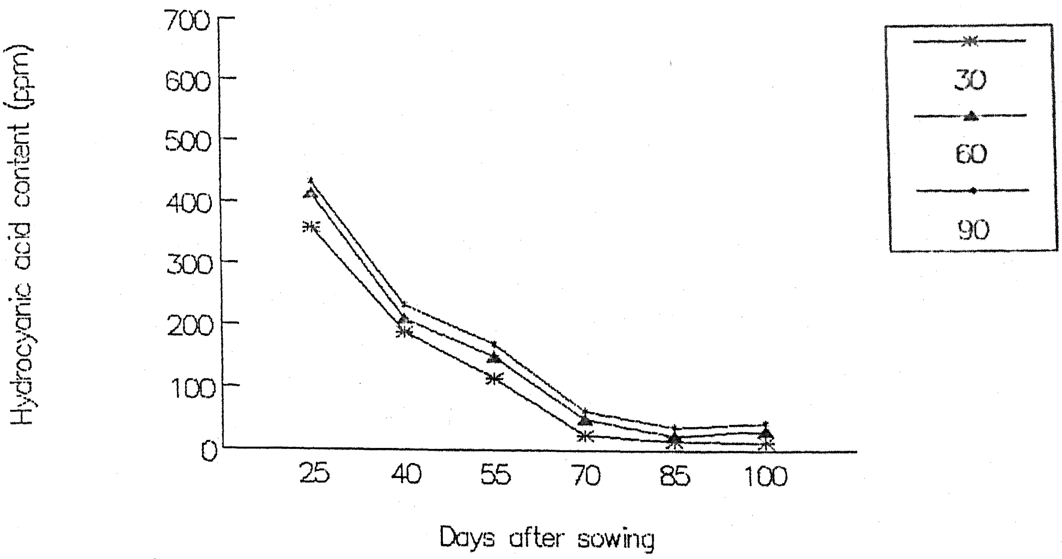


FIG 22: HYDROCYANIC ACID CONTENT (ppm)

NITROGEN LEVELS (kg/ha) , 1988



1989

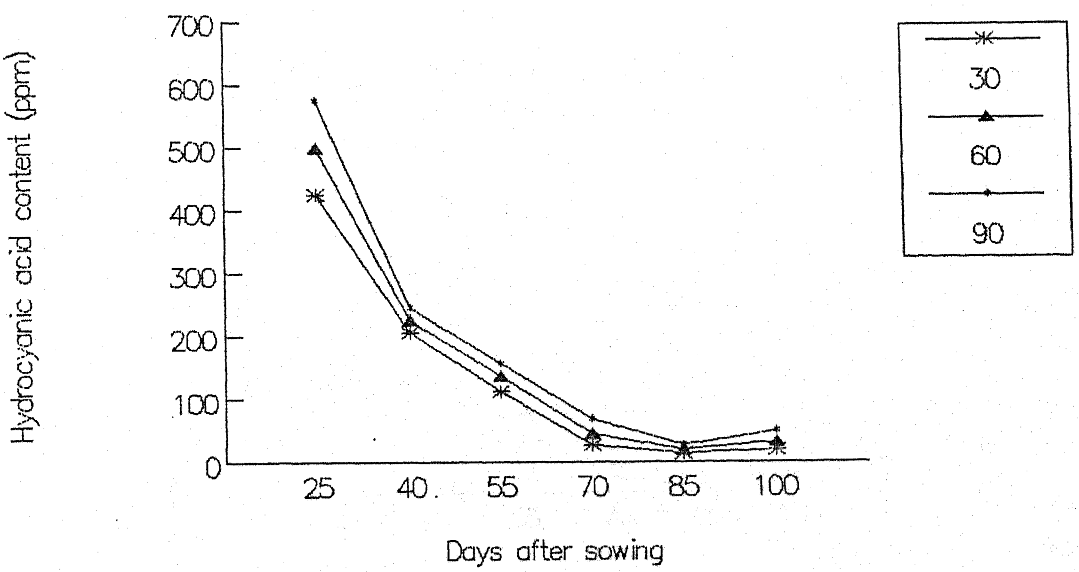
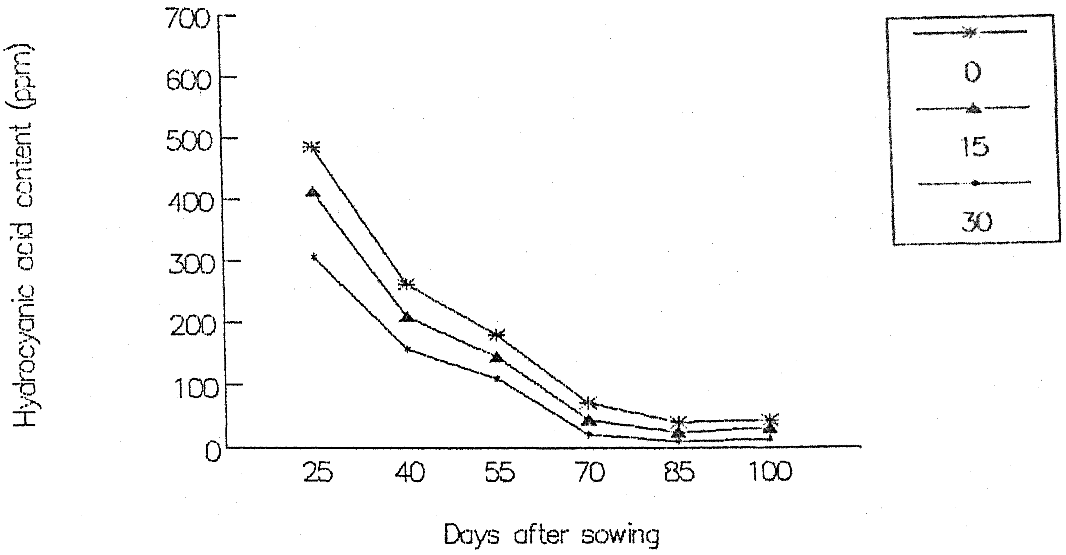
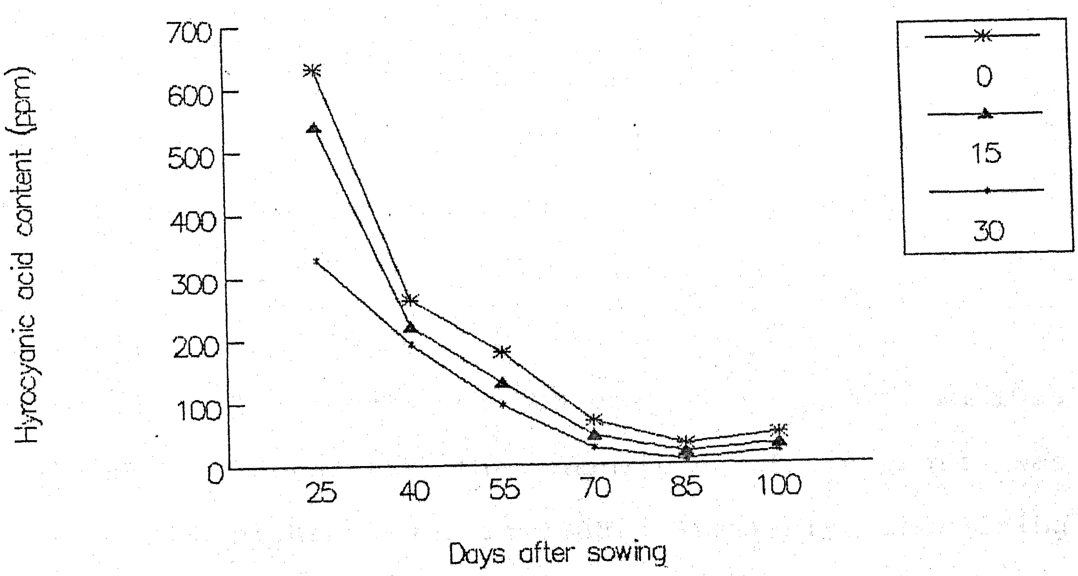


FIG 23: HYDROCYANIC ACID CONTENT (ppm)

SULPHUR LEVELS (kg/ha) , 1988



1989



In 1989, variety PC-6 continued to exhibit lower HCN content from 25 to 70 DAS. At 25 and 70 DAS it was at par with HC-136 but significantly lower than HD-2. At 40 and 55 days after sowing the differences became tangible and PC-6 showed significantly lower HCN content than HC-136 and HD-2 which also differed significantly from each other. At 85 DAS the HCN content in PC-6 coinciding with its harvesting date was half (19.8 ppm) to that of HC-136 (38.6 ppm).

At harvest, in both the years, the variation in HCN content of sorghum varieties was significant. Variety HC-136 contained significantly lowest HCN content as compared to PC-6 and HD-2. PC-6 also exhibited significantly lower HCN content than HD-2.

The increasing doses of nitrogen from 30 to 90 kg N/ha progressively increased the concentration of HCN at all the stages of growth in both the years. The overall magnitude of increase was more pronounced in 1989 than in 1988 at 25 days of growth. At 40 and 55 DAS the effect of nitrogen in increasing the HCN content was comparatively more in 1988 than in 1989. This trend was also maintained at harvest. Increasing the nitrogen from 30 to 60 kg/ha exhibited greater effect in increasing HCN content in plants in 1989 at 25 DAS. Thereafter the magnitude of increase was maintained at higher level in 1988. Similarly, increasing the nitrogen level from 60 to 90 kg N/ha caused three fold

increase in HCN content at 25 days in 1989 as compared to 1988. At 40 and 55 days of growth, however, the effect was almost similar in both the years. Subsequently, the magnitude of increase was relatively higher in second year of experimentation. The observations, therefore, suggest that the effect of nitrogen in increasing the HCN content was more at initial stages of growth and more so in 1989.

The increase in HCN concentration due to increase in nitrogen levels from 30 to 60 and also from 60 to 90 kg/ha was significant at 25, 40 and 70 days of crop growth in both the years. At 55 days of growth the difference between 60 and 90 was, however, not significant. At harvest the successive differences in HCN content workedout to be significant in 1988 but in 1989 the HCN content at 30 and 60 kg N/ha was at par. At harvest on an average of 30, 60 and 90 kg N/ha gave HCN concentration of 16.6, 32.0 and 46.4 ppm, respectively.

The HCN concentration in plant decreased with increasing doses of sulphur from 0 to 30 kg S/ha at all the growth stages in both the years. The magnitude of decrease, however, differed with years and stages of crop growth. The magnitude of reduction in HCN concentration due to sulphur nutrition was more in 1989 than in 1988 at 25 days of crop growth. Barring 55 days of growth, the level of reduction was greater in 1988 than in 1989.

At 25 days of growth also, application of 15 and 30 kg S/ha caused greater reduction in HCN content in 1989 than in 1988 over their preceding doses of 0 and 15 kg S/ha. At 40 days of growth, however, the degree of reduction was more in 1988 as compared to 1989 with successive increase in sulphur dose. At 55 DAS the effect of successive increments was similar in 1988 but in 1989 the first increment of sulphur from 0 to 15 kg/ha exhibited nearly $1\frac{1}{2}$ times reduction in HCN concentration as compared to its increase from 15 to 30 kg/ha.

Increasing the sulphur levels from 0 to 30 kg S/ha caused significant reduction in HCN concentration at all the stages of crop growth in both the years. The successive levels of reduction were significant at all the stages except at harvesting stage in 1988 where the difference between 15 and 0 kg did not reach the level of significance.

In 1988, (Table 32 and 33) the interaction V x N was significant at 25, 40 and at harvest (70 DAS in HD-2, 85 DAS in PC-6 and 100 DAS in HC-136). Variety PC-6 receiving 30 kg N/ha resulted in significantly lowest HCN concentration at 25 and 40 DAS. At 70 days, however, it did not differ from variety HC-136 fertilized with 30 kg N/ha. The highest HCN content was observed with variety HD-2 receiving 90 kg N/ha at these stages. At harvesting stage, however, variety HC-136 exhibited significantly lowest HCN content at all the levels of fertilizer

Table 32. Effect of V x N and V x S interactions on hydrocyanic acid content (ppm) in 1988.

Nitrogen (kg/ha)	25 DAS Varieties PC-6	25 DAS Varieties HD-2	25 DAS Varieties HC-136	40 DAS Varieties PC-6	40 DAS Varieties HD-2	40 DAS Varieties HC-136	Sulphur (kg/ha)	25 DAS Varieties PC-6	25 DAS Varieties HD-2	25 DAS Varieties HC-136
30	307.3 (17.4)	431.0 (20.6)	336.7 (18.3)	148.0 (12.1)	208.3 (14.4)	208.0 (14.4)	0	409.3 (20.2)	596.3 (24.4)	454.7 (21.3)
60	334.0 (18.2)	529.0 (22.8)	380.0 (19.4)	168.3 (12.8)	238.0 (15.4)	221.0 (14.8)	15	302.7 (17.4)	564.0 (23.7)	371.7 (19.3)
90	340.7 (18.4)	553.0 (23.4)	405.7 (20.1)	196.7 (14.0)	261.0 (16.1)	240.0 (15.4)	30	270.0 (16.4)	352.7 (18.8)	296.0 (17.2)
SEm ±	0.16			0.20			0.16			
CD at 5%	0.5			0.7			0.5			

Table 33. Effect of V x N and N x S interactions on hydrocyanic acid content (ppm) in 1988.

Nitrogen (kg/ha)	70 DAS Varieties PC-6	HD-2	HC-136	At harvest Varieties PC-6	HD-2	HC-136	Sulphur (kg/ha)	At harvest Nitrogen (kg/ha) 30	60	90
30	25.7 (4.3)	27.3 (4.4)	19.3 (3.7)	13.7 (3.2)	27.3 (4.4)	0 (0.6)	0	52.7 (7.3)	71.7 (8.4)	90.7 (9.4)
60	35.0 (5.9)	78.7 (8.8)	36.7 (5.9)	16.7 (3.7)	48.7 (8.8)	0 (0.6)	15	19.7 (4.4)	51.7 (7.0)	63.0 (7.8)
90	41.0 (6.3)	98.3 (9.8)	51.3 (7.0)	29.0 (5.4)	98.3 (9.8)	4.0 (1.6)	30	0 (0.6)	27.0 (5.1)	37.0 (6.0)
(SEm ±)	0.19			0.63			0.19			
(CD at 5%)	0.6			2.1			0.6			

nitrogen as compared to other combinations. The HCN content of variety HD-2 at 60 and 90 kg N/ha was at par but significantly greater than other combinations.

The significant V x S interaction at 25 DAS indicated that variety PC-6 receiving 30 kg S/ha contained significantly lowest HCN whereas variety HD-2 without sulphur nutrition showed highest HCN conccentration. The interaction between the levels of nitrogen and sulphur was significant at harvesting stage. The significantly lowest HCN content occurred when crop was fertilized with 30 kg/ha each of nitrogen and sulphur. On the other hand, significantly highest HCN concentration occurred when crop was fertilized with 90 kg N/ha alone.

In 1989, (Table 34) the significant interaction V x N at 40 DAS revealed that variety PC-6 fertilized with 30 kg N/ha showed significantly lower HCN content but did not differ from its HCN content obtained at 60 kg N/ha which in turn, was at par with that of 90 kg N/ha. On the other hand, variety HD-2 fertilized with 90 kg N/ha registered significantly highest HCN content (334.0 ppm). The interaction V x S was significant at 25 and 40 days after sowing. At 25 DAS variety PC-6 receiving 30 kg S/ha showed significantly lowest HCN concentration but did not differ from HD-2 and HC-136 fertilized with the same dose of sulphur. However, the effect of 15 kg S/ha was statistically not tangible with variety HD-2 showing the highest HCN content.

Table 34. Effect of V x S and V x N interactions on hydrocyanic acid content (ppm) in 1989.

Sulphur (kg/ha)	25 DAS Varieties			40 DAS Varieties			Nitrogen (kg/ha)	40 DAS Varieties		
	PC-6	HD-2	HC-136	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136
0	173.3 (22.7)	346.0 (27.9)	274.3 (24.6)	173.3 (13.2)	346.0 (18.6)	274.3 (16.6)	30	148.3 (12.2)	250.7 (15.8)	221.7 (14.8)
15	157.7 (21.5)	270.0 (26.7)	253.3 (21.0)	157.7 (12.6)	270.0 (16.4)	235.3 (15.4)	60	155.3 (12.5)	288.0 (17.0)	232.7 (15.2)
30	146.7 (17.0)	258.7 (18.8)	174.7 (18.3)	146.7 (12.1)	256.7 (16.0)	174.7 (13.2)	90	174.0 (13.2)	334.0 (18.3)	230.0 (15.1)
SEm ±	0.57			0.23				0.23		
CD at 5%	1.9			0.8				0.8		

At 40 DAS though variety PC-6 recorded lowest HCN concentration at 30 kg S/ha, but was at par with its HCN contgent at 15 kg S/ha. Variety HD-2 without sulphur nutrition exhibited significantly highest HCN content (346.0 ppm).

Fibre Fractions:

Neutral Detergent Fibre (NDF): The data on NDF content (Table 35 and Fig. 24) indicated that the average NDF values were slightly higher in 1988 (63.94%) than in 1989 (62.57%). There was no significant variation in NDF content in 1988 among varieties. However, the lowest NDF content was observed in variety HC-136 and highest in PC-6. In 1989, all the varieties differed significantly from each other in so far as the NDF content was concerned. Variety HC-136 was found to contain significantly lowest NDF content whereas variety PC-6 exhibited the highest value.

The effect of nitrogen and sulphur nutrition on NDF content was not significant in both the years of investigation. In 1988, application of 30 to 90 kg N/ha increased the NDF content marginally but in 1989, NDF remained practically constant at all the levels of nitrogen. Application of 15 and 30 kg S/ha increased the NDF content by 1.11 and 1.18 unit in 1988 and by 0.34 and 1.40 unit in 1989 over no sulphur treatment, respectively.

Acid Detergent Fibre (ADF): The data on ADF content have been presented in Table 35 and depicted in Fig. 25.

Table 35. Neutral detergent fibre and acid detergent fibre content (%)

Treatments	Neutral detergent fibre (%)		Acid detergent fibre (%)	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	67.86	64.65	44.99	43.62
HD-2	66.47	62.95	43.41	43.09
HC-136	57.51	60.10	34.29	41.18
SEm ±	3.123	0.406	0.691	0.439
CD at 5%	NS	1.41	2.25	1.07
Nitrogen levels (kg/ha)				
30	62.58	62.64	41.17	42.36
60	64.43	62.48	40.67	43.15
90	64.83	62.58	40.85	43.60
SEm ±	3.123	0.406	0.691	0.439
CD at 5%	NS	NS	NS	NS
Sulphur levels (kg/ha)				
0	63.18	61.99	41.04	42.35
15	64.29	62.33	40.69	41.94
30	64.36	63.39	40.96	42.60
SEm ±	3.123	0.406	0.691	0.439
CD at 5%	NS	NS	NS	NS
General Mean	63.94	62.57	40.90	42.30

FIG 24: NEUTRAL DETERGENT FIBRE CONTENT

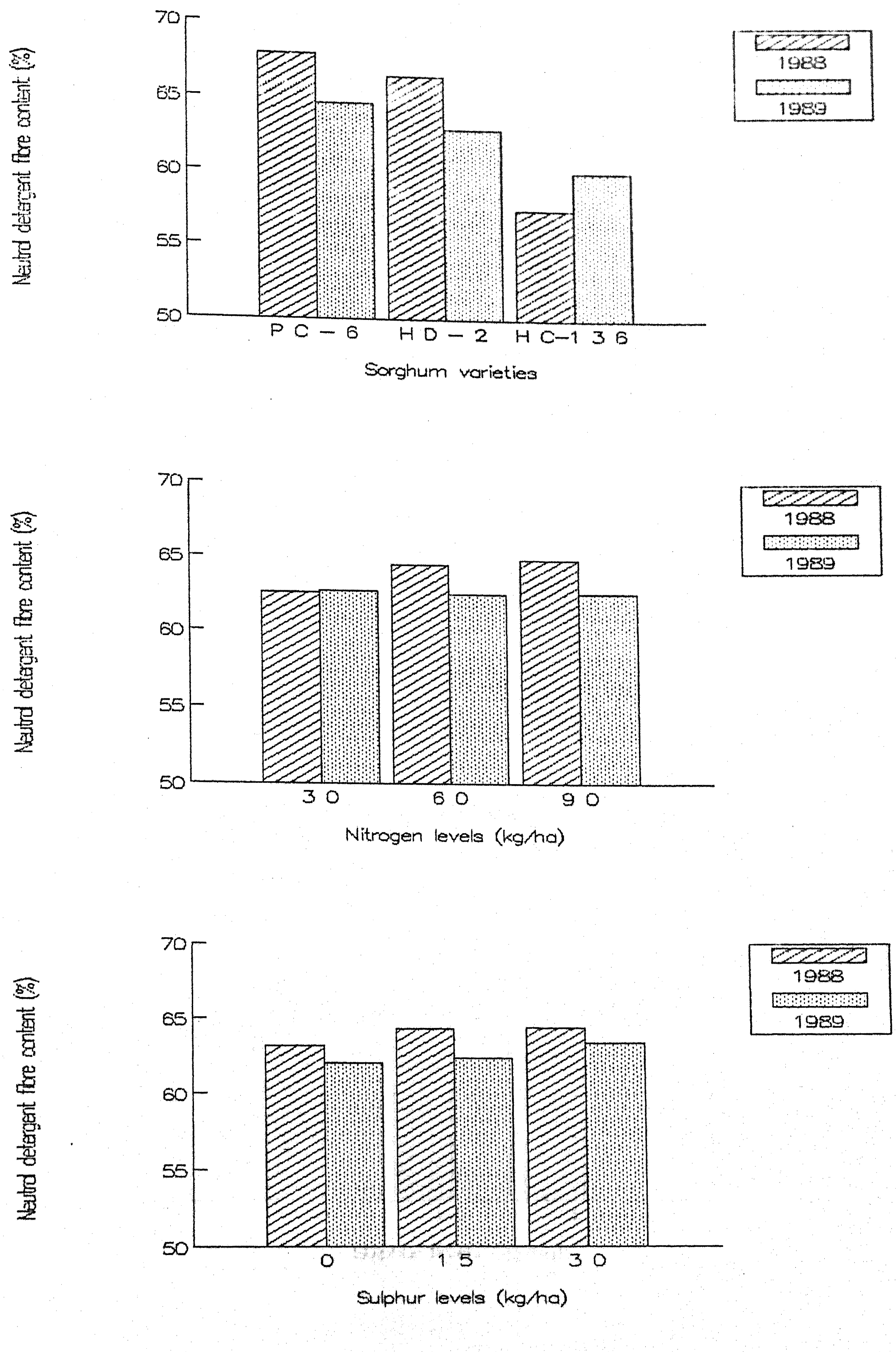
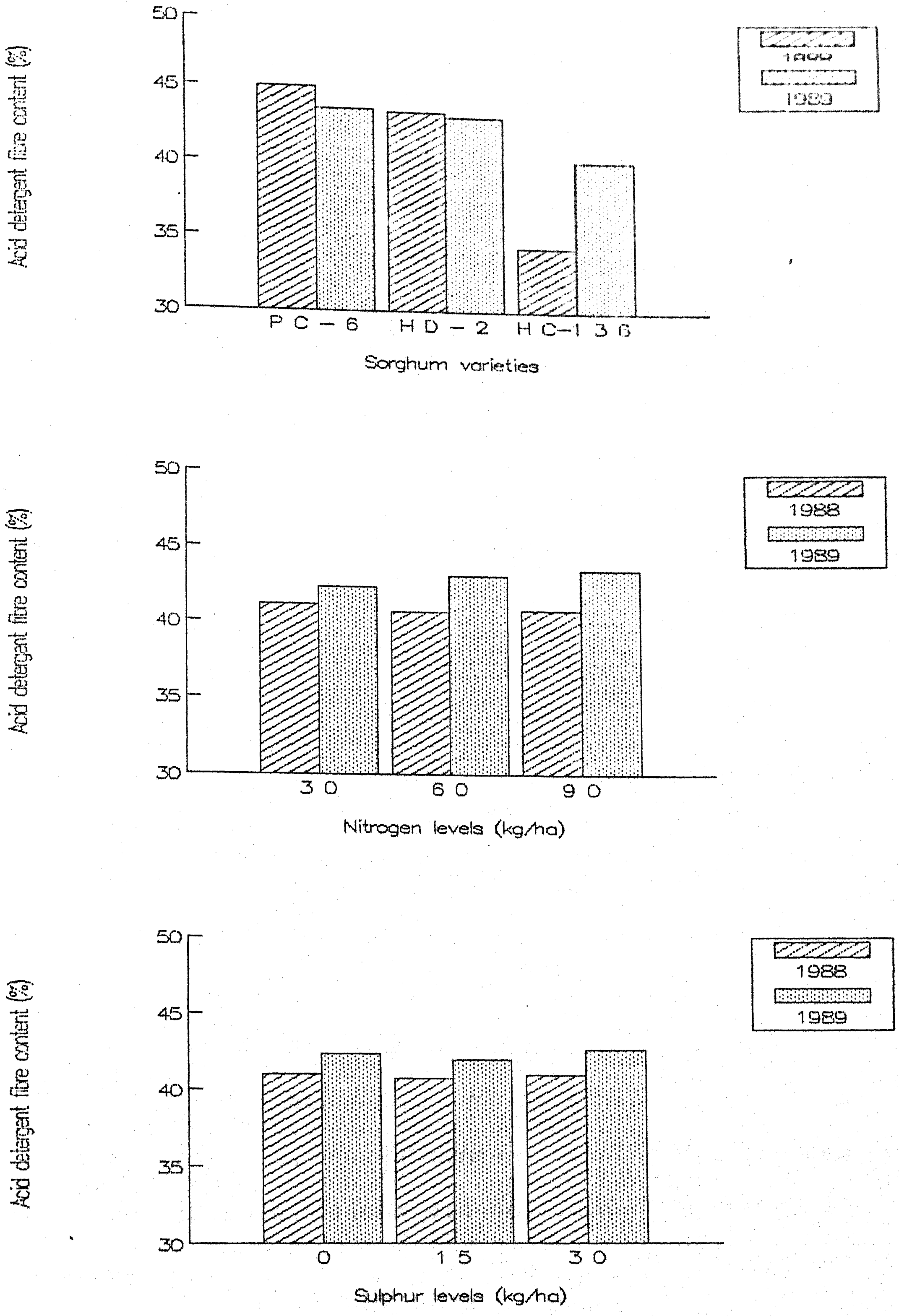


FIG 25: ACID DETERGENT FIBRE CONTENT



The average ADF content in sorghum was 40.90 per cent in 1988 and 42.30 per cent in 1989. The sorghum varieties differed significantly in ADF content and HC-136 exhibited significantly lowest values as compared to HD-2 and PC-6 which in turn did not differ between themselves in both the years.

The nitrogen nutrition did not exercise its effect significantly in altering the ADF content of sorghum varieties in both the years. In 1988, the lowest value of ADF was recorded at 60 kg N/ha while in 1989, it was at 30 kg N/ha.

The application of sulphur had no significant effect on the ADF content of sorghum varieties during both the years of experimentation. The plants fertilized with 15 kg S/ha registered the lowest value of ADF.

The interactions V x N, V x S and N x S were significant for NDF content in 1989 (Table 36). Variety HC-136 fertilized with 90 kg N/ha resulted in significantly lower NDF content of 58.16 per cent as compared to other combinations. However, it did not differ significantly from its interaction with 30 and 60 kg N/ha. Though the combination of variety HC-136 with 15 kg S/ha was found to give significantly lower NDF content but did not differ statistically from its combination with 30 kg S/ha. Application of 30 kg N alone gave lower NDF content but the differences from other N x S combinations did not reach the level of significance.

Table 36. Effect of V x N, V x S and N x S interactions on neutral detergent fibre content (%) in 1989.

Nitrogen (kg/ha)	Varieties			Sulphur (kg/ha)	Varieties			Nitrogen (kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	63.84	63.11	60.97	0	63.63	61.03	61.31	60.44	63.78	61.75
60	65.34	61.38	60.73	15	65.28	63.18	58.84	63.15	62.02	61.81
90	64.77	64.37	58.61	30	65.04	63.97	60.58	64.33	61.66	64.18

SEm ± 0.704

CD at 5% 2.44

Cellulose: There was practically no difference in cellulose content in two years of experimentation (Table 37 and Fig. 26). Variety HC-136 recorded significantly lowest cellulose content as compared to other sorghum varieties during both the years. Varieties HD-2 and PC-6 also differed significantly from each other in 1988 but were at par in 1989.

No significant variation in cellulose content was observed either due to different doses of nitrogen or sulphur in both the years. However, comparatively lower cellulose content was found with 90 kg N/ha. There was no particular trend with respect to sulphur nutrition in two years.

Hemicellulose: The perusal of the data in Table 37 and Fig. 27 would reveal that the average hemicellulose content was comparatively higher in 1988 (23.06%) than in 1989 (20.27%). Sorghum varieties were not found to differ significantly in hemicellulose content in both the years.

The hemicellulose content remained unaltered by nitrogen and sulphur fertilization in both the years. On an average increasing doses of nitrogen from 30 to 90 kg N/ha increased the hemicellulose from 20.87 to 22.59 per cent. Similarly, the application of 30 kg S/ha gave the hemicellulose content of 22.31 per cent over the control (20.89%).

Table 37. Cellulose and hemi-cellulose content (%)

Treatments	Cellulose content (%) 1988	Cellulose content (%) 1989	hemi-cellulose content (%) 1988	hemi-cellulose content (%) 1989
Sorghum varieties				
PC-6	36.65	35.31	22.92	21.03
HD-2	34.10	34.20	23.05	19.85
HC-136	28.89	31.92	23.22	19.92
SEm ±	0.542	0.514	1.101	0.706
CD at 5%	1.77	1.78	NS	NS
Nitrogen levels (kg/ha)				
30	33.45	33.84	21.45	20.28
60	33.85	34.52	23.76	19.33
90	32.34	33.08	23.98	21.20
SEm ±	0.542	0.514	1.101	0.706
CD at 5%	NS	NS	NS	NS
Sulphur levels (kg/ha)				
0	33.31	33.86	22.14	19.64
15	33.35	33.56	23.64	19.33
30	32.99	34.01	23.41	21.20
SEm ±	0.542	0.514	1.101	0.706
CD at 5%	NS	NS	NS	NS
General Mean	33.22	33.81	23.06	20.27

FIG 26: CELLULOSE CONTENT (%)

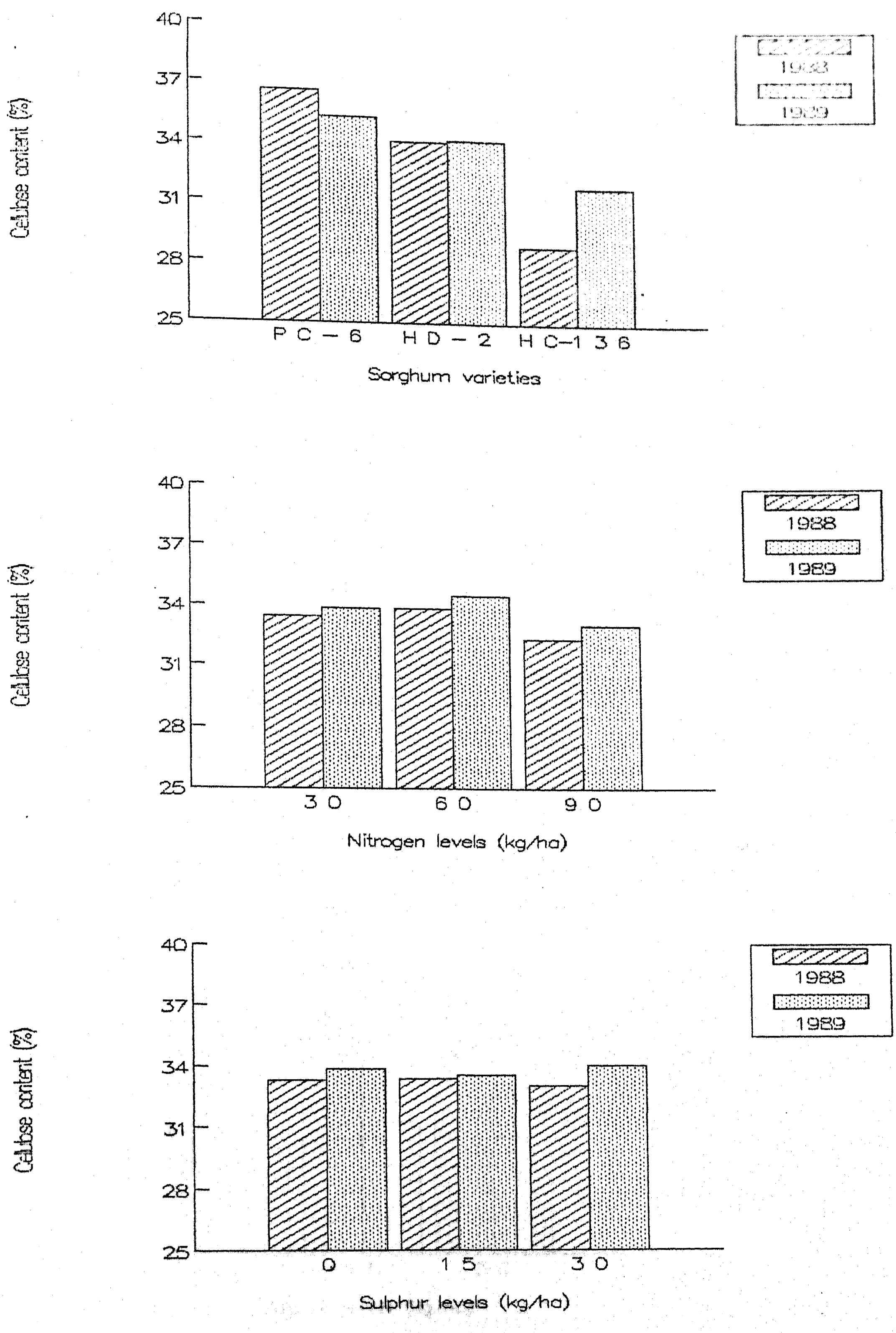
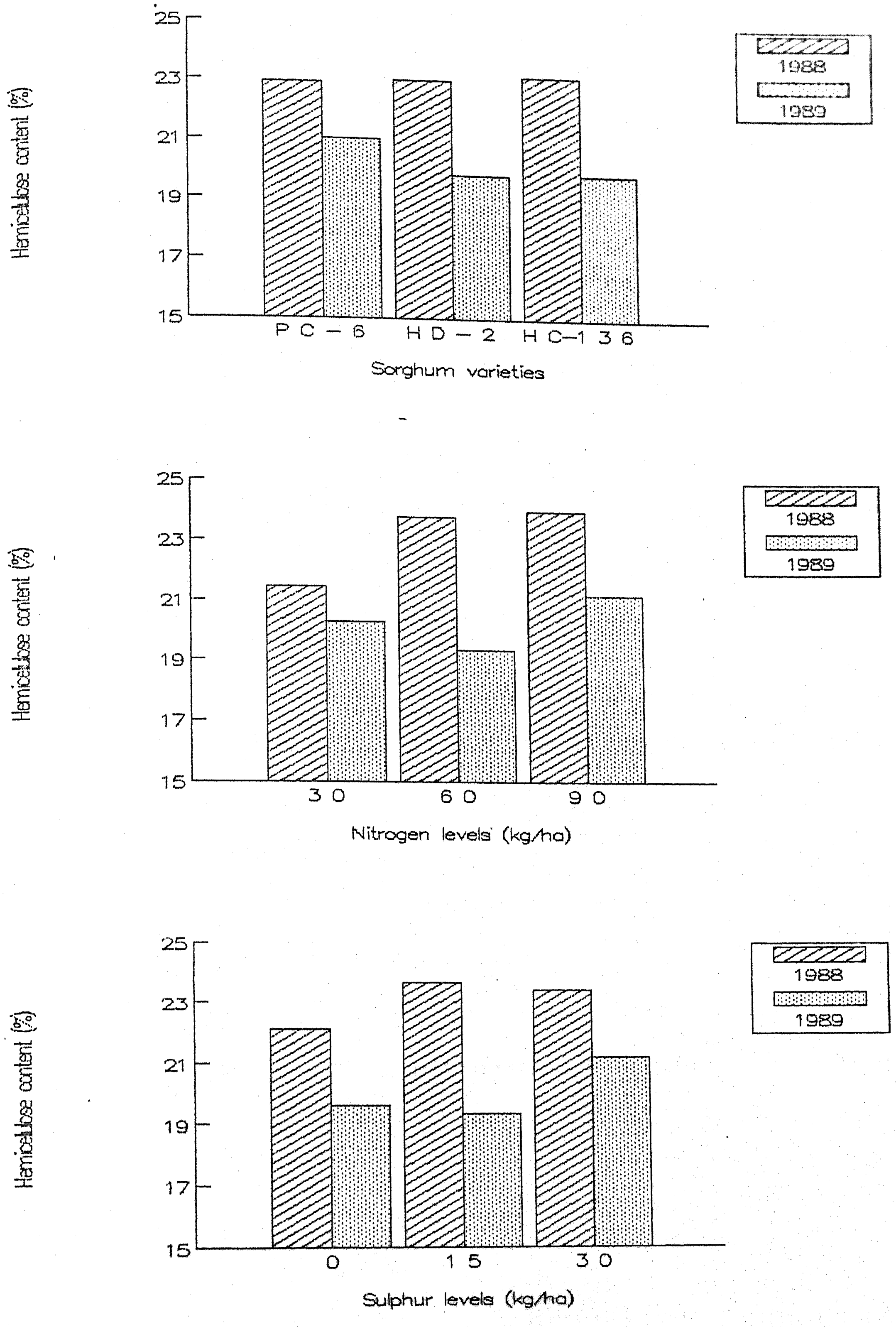


FIG 27: HEMICELLULOSE CONTENT (%)



<u>Lignin</u> : The data on lignin content are presented in Table 38 and depicted in Fig. 28. The mean lignin content was lower in 1988 (5.72%) against 6.07 per cent in 1989. The varietal differences in lignin content were significant in 1988 and variety HC-136 gave the lowest lignin content as compared to HD-2 and PC-6 which in turn did not differ significantly from each other. In 1989, however, the difference in lignin content of the sorghum varieties was not tangible.

Nitrogen and sulphur nutrition did not exercise significant effect on lignin content in both the years. However, application of 30 kg N/ha resulted in lower lignin content consistently. Increasing doses of sulphur, however, marginally increased the lignin content in 1989.

<u>Plant silica</u>: The perusal of the data (Table 38 and Fig.29) indicated that plant silica content was practically the same in both the years (2.62-2.66%). Further, the silica content remained unaffected due to varieties and nitrogen and sulphur levels. However, lower silica content was observed in PC-6 and the highest in HD-2. No definite trend in silica content was observed with respect to different levels of nitrogen and sulphur in two years.

Table 38. Lignin and plant silica content (%)

Treatments	Lignin content (%) 1988	Lignin content (%) 1989	Silica content (%) 1988	Silica content (%) 1989
Sorghum varieties				
PC-6	6.39	5.98	2.46	2.53
HD-2	6.31	6.38	2.98	2.75
HC-136	4.55	5.87	2.52	2.58
SEm ±	0.240	0.232	0.173	0.218
CD at 5%	0.78	NS	NS	NS
Nitrogen levels (kg/ha)				
30	5.48	5.91	2.57	2.72
60	6.09	6.22	2.79	2.86
90	5.57	6.09	2.61	2.28
SEm ±	0.240	0.232	0.173	0.218
CD at 5%	NS	NS	NS	NS
Sulphur levels (kg/ha)				
0	5.96	6.03	2.66	2.67
15	5.72	6.07	2.67	2.47
30	5.47	6.12	2.63	2.72
SEm ±	0.240	0.232	0.173	0.218
CD at 5%	NS	NS	NS	NS
General Mean	5.72	6.07	2.66	2.62

FIG 28: LIGNIN CONTENT (%)

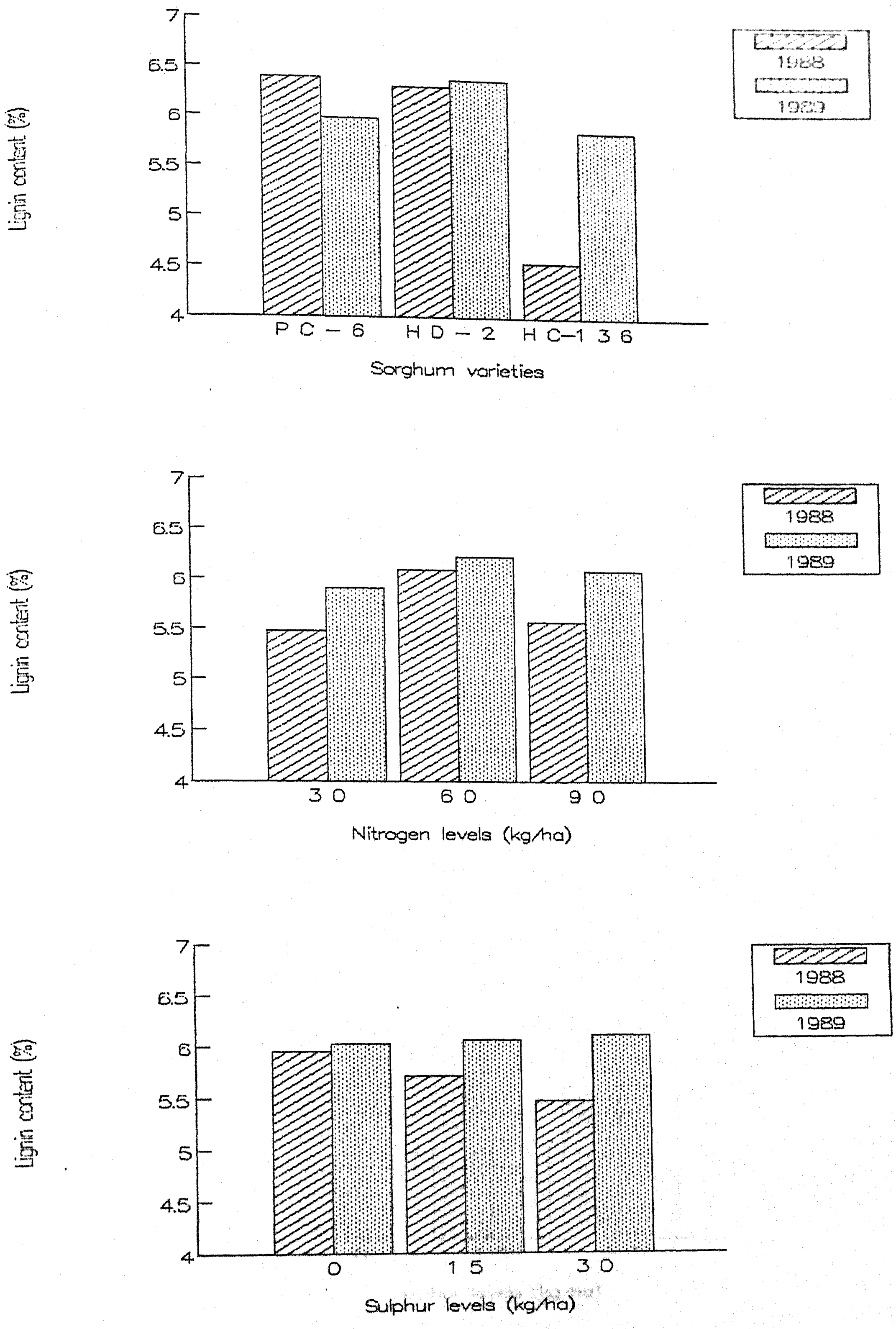
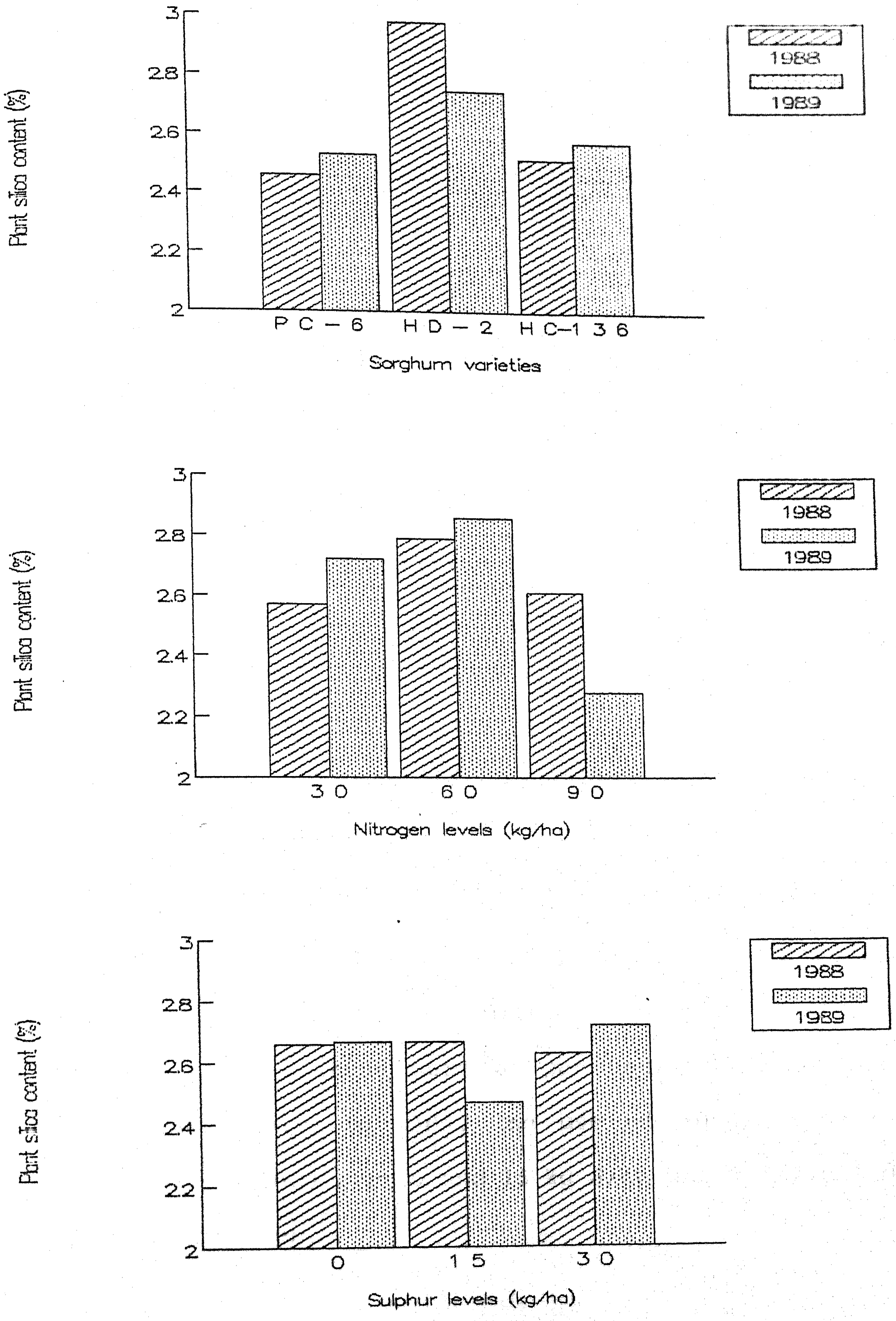


FIG 29: PLANT SILICA CONTENT (%)



Nutrient content:

The data on nitrogen and sulphur content in plants at harvest have been presented in Table 39 and Fig. 30 & 31.

Nitrogen content:

The perusal of the data showed that the average nitrogen content was 0.83 per cent in 1988 and 0.87 per cent in 1989. In 1988, varieties HD-2 and HC-136 showed statistically similar nitrogen content but significantly greater than PC-6. In 1989, however, the sorghum varieties differed significantly in nitrogen content, the highest being with HD-2 (1.03%).

Nitrogen application exercised its significant effect in increasing the nitrogen content in both the years. Application of 90 kg N/ha exhibited significantly highest nitrogen content over 30 kg N/ha in both the years. In 1988, however, the difference between 90 and 60 kg N/ha was not significant, whereas in 1989 all the doses differed significantly from each other.

In 1988, application of 15 and 30 kg S/ha resulted in significantly higher nitrogen content over control treatment, but these were at par between themselves. On the other hand, in 1989, the use of 30 kg S/ha gave a significant lead over 0 and 15 kg S/ha which did not differ from each other.

Table 39. Nitrogen and sulphur content in plant (%)

Treatments	Nitrogen content (%) 1988	Nitrogen content (%) 1989	Sulphur content (%) 1988	Sulphur content (%) 1989
Sorghum varieties				
PC-6	0.768	0.816	0.125	0.129
HD-2	0.874	1.031	0.177	0.143
HC-136	0.857	0.769	0.178	0.116
SEm ±	0.0183	0.0115	0.0100	0.0056
CD at 5%	0.059	0.038	0.033	NS
Nitrogen levels (kg/ha)				
30	0.763	0.783	0.131	0.105
60	0.839	0.852	0.168	0.123
90	0.896	0.981	0.180	0.160
SEm ±	0.0183	0.0115	0.0100	0.0056
CD at 5%	0.059	0.038	0.033	NS
Sulphur levels (kg/ha)				
0	0.710	0.796	0.100	0.098
15	0.839	0.843	0.157	0.127
30	0.896	0.977	0.223	0.163
SEm ±	0.0183	0.0115	0.0100	0.0056
CD at 5%	0.059	0.038	0.033	0.018
General Mean	0.830	0.870	0.159	0.229

FIG 30: NITROGEN CONTENT IN PLANT (%)

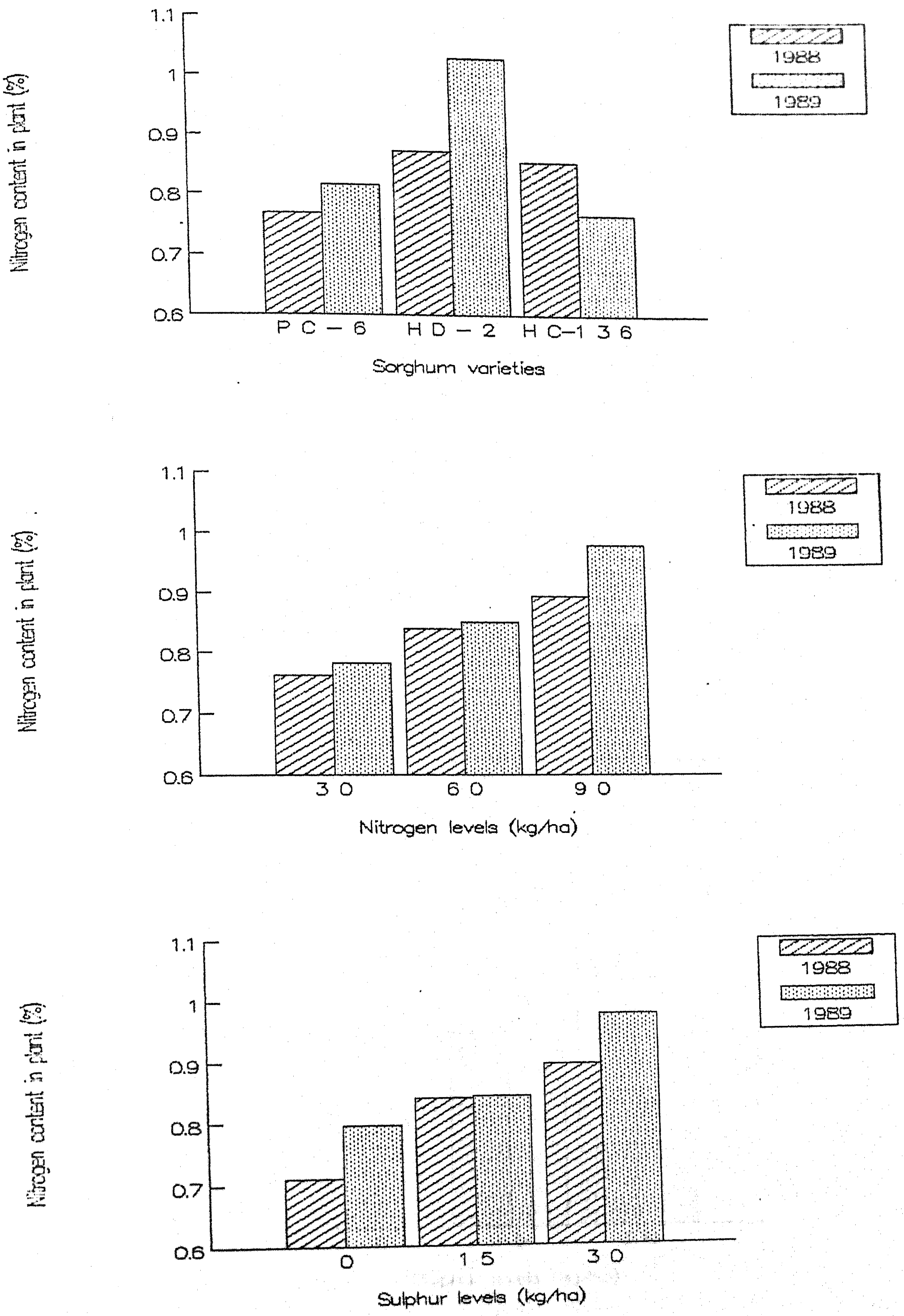
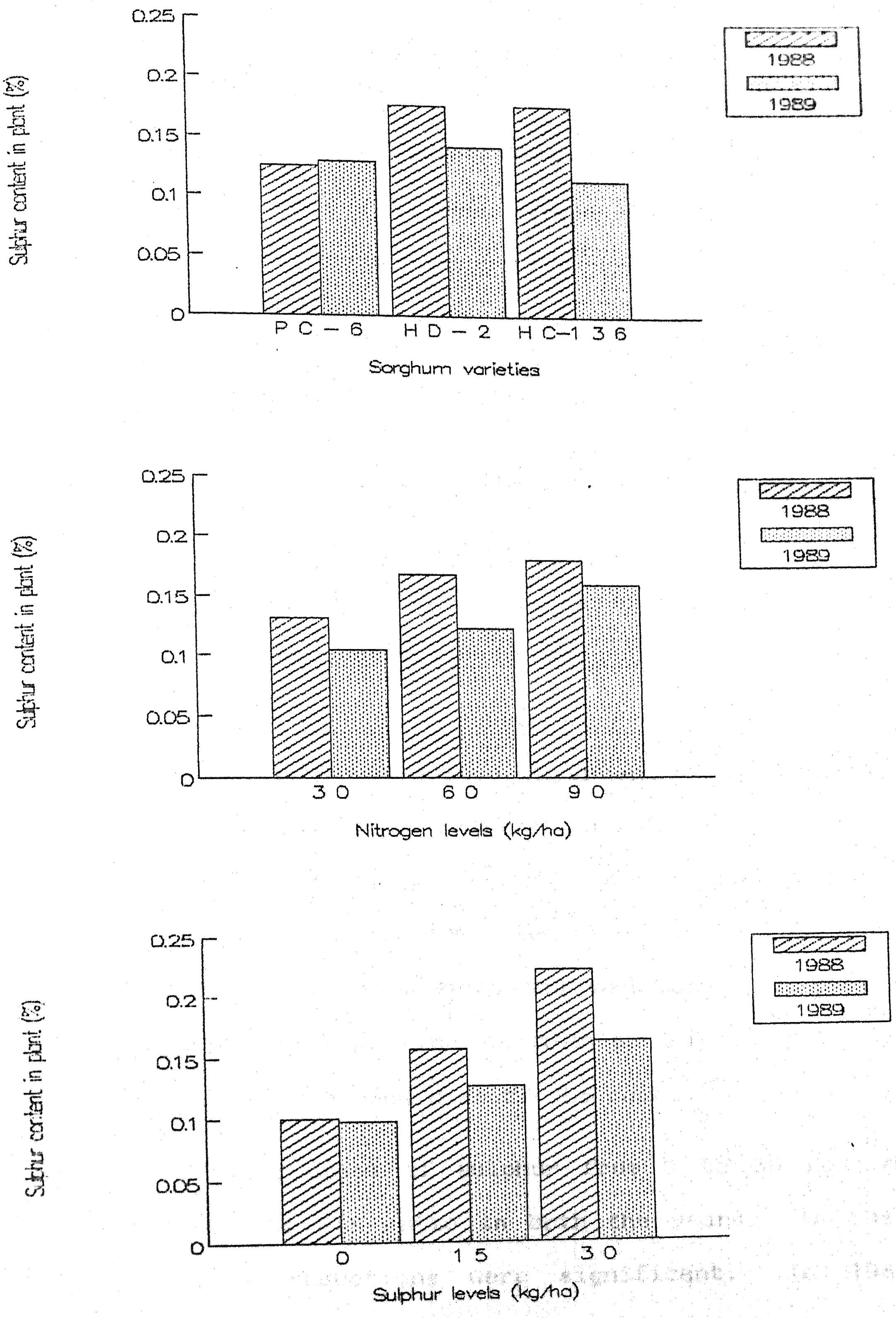


FIG 31: SULPHUR CONTENT IN PLANT (%)



Sulphur content:

The average sulphur content in plants was 0.16 per cent in 1988 and 0.23 per cent in 1989. The sulphur content of varieties HC-136 and HD-2 remained the same but significantly greater than PC-6 in 1988. In 1989, however, varietal differences in sulphur content were statistically not significant.

Increasing doses of nitrogen increased the sulphur content in plants in both the years but the effect was significant only in 1988. It follows that 60 and 90 kg N/ha resulted in similar sulphur content but significantly greater than 30 kg N/ha.

The effect of sulphur nutrition on its content in plants was tangible and each additional dose of 15 kg S/ha increased its content significantly in both the years.

N:S ratio: The data on N:S ratio in plants presented in Table 40 and Fig. 32 revealed that the mean N:S ratio was 5.89 in 1988 and 7.12 in 1989.

In 1988, variety PC-6 gave significantly wider N:S ratio of 6.94 over HD-2 and HC-136 which did not differ between themselves. In 1989, though, the N:S ratio varied from 6.81 with HC-136 to 7.43 with HD-2 but the differences were not significant.

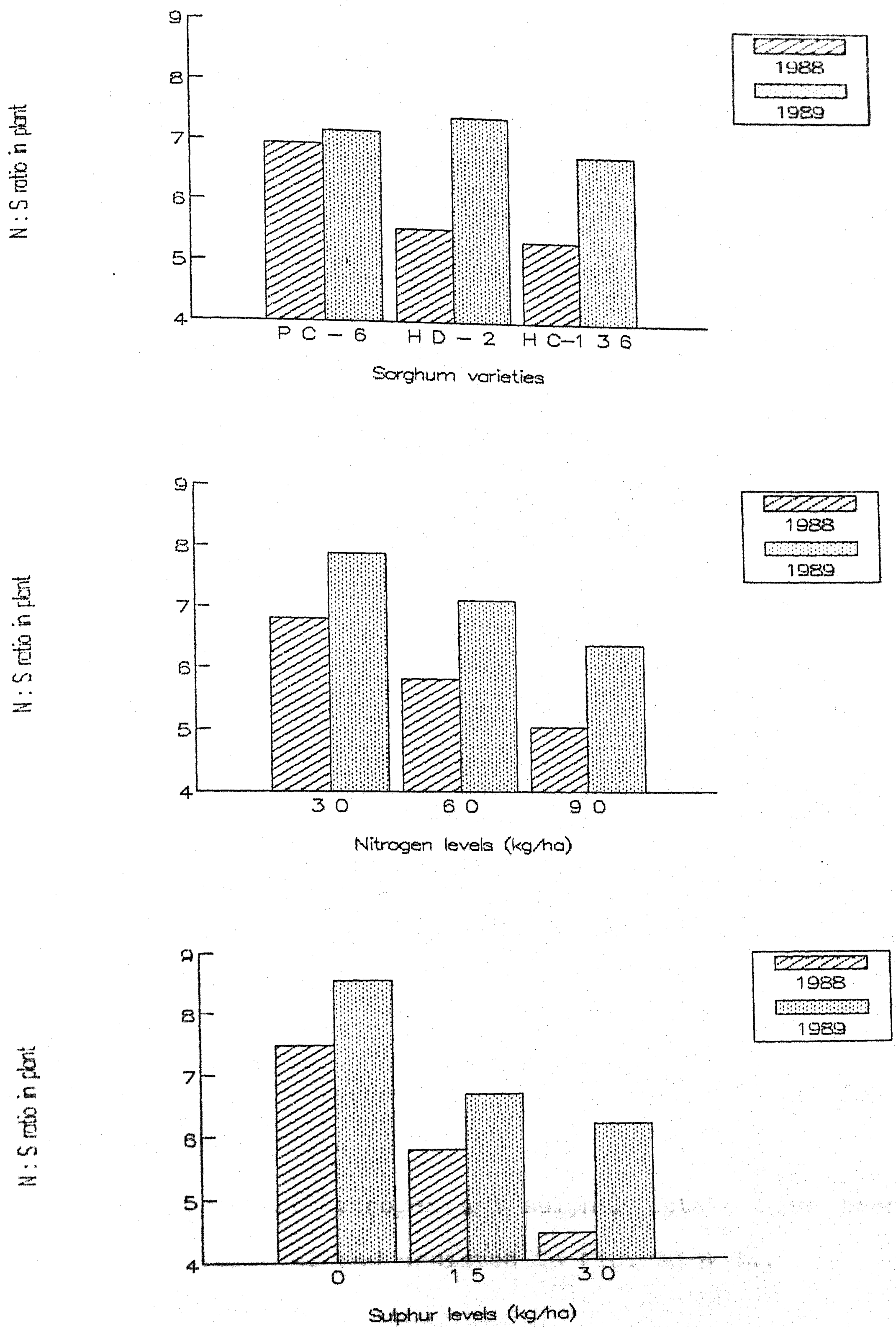
Nitrogen did not show significant variation in N:S ratio in both the years, however, increasing doses of nitrogen from 30 to 90 kg N/ha slightly narrowed down the N:S ratio.

Increasing doses of sulphur from 0 to 30 kg S/ha narrowed down the N:S ratio in both the years. In 1988, the successive reductions were significant. In 1989,

Table 40. N : S ratio in plant

Treatments	1988	1989
Sorghum varieties		
PC-6	6.94	7.16
HD-2	5.45	7.43
HC-136	5.34	6.81
SEm ±	0.390	0.265
CD at 5%	1.27	NS
Nitrogen levels (kg/ha)		
30	6.80	7.88
60	5.83	7.12
90	5.05	6.39
SEm ±	0.390	0.265
CD at 5%	1.27	0.86
Sulphur levels (kg/ha)		
0	7.47	8.53
15	5.78	6.67
30	4.43	6.19
SEm ±	0.390	0.265
CD at 5%	1.27	0.86
General Mean	5.89	7.12

FIG 32: N:S RATIO IN PLANT



however, the N:S ratio with 15 and 30 kg S/ha was of the same order but significantly lower than the control treatment.

There was significant interaction between varieties and sulphur levels in so far as N:S ratio was concerned (Table 41). The significantly lowest N:S ratio of 4.95 was observed with variety PC-6 fertilized with 30 kg S/ha which was at par with variety HC-136 receiving the same dose of sulphur. Significantly highest N:S ratio occurred with variety PC-6 without sulphur nutrition.

Table 41. Effect of V x S interaction on N:S ratio in plants at harvest in 1989.

Sulphur (kg/ha)	Varieties		
	PC-6	HD-2	HC-136
0	9.86	8.19	7.54
15	6.65	6.70	6.65
30	4.95	7.38	6.22

SEm ± 0.458

CD at 5% 1.49

Nutrient uptake:

The data on nitrogen and sulphur uptake have been presented in Table 42 and depicted in Fig. 33 & 34.

Table 42. Nitrogen and sulphur uptake (kg/ha)

Treatments	Nitrogen uptake (kg/ha)		Sulphur uptake (kg/ha)	
	1988	1989	1988	1989
Sorghum varieties				
PC-6	89.23	91.19	14.90	14.97
HD-2	97.37	116.32	19.95	16.46
HC-136	131.88	103.60	27.75	15.76
SEm ±	2.571	1.828	1.528	0.617
CD at 5%	8.38	5.96	4.98	NS
Nitrogen levels (kg/ha)				
30	83.76	75.67	14.74	10.40
60	105.70	101.54	21.43	14.74
90	129.02	133.89	26.42	22.09
SEm ±	2.571	1.828	1.528	0.617
CD at 5%	8.38	5.96	4.98	2.09
Sulphur levels (kg/ha)				
0	83.26	79.71	11.84	9.98
15	104.34	98.61	19.75	14.97
30	130.89	132.79	31.01	22.24
SEm ±	2.571	1.828	1,528	0.617
CD at 5%	8.38	5.96	4.28	2.09
General Mean	106.16	103.70	20.87	15.74

FIG 33: NITROGEN UPTAKE (kg/ha)

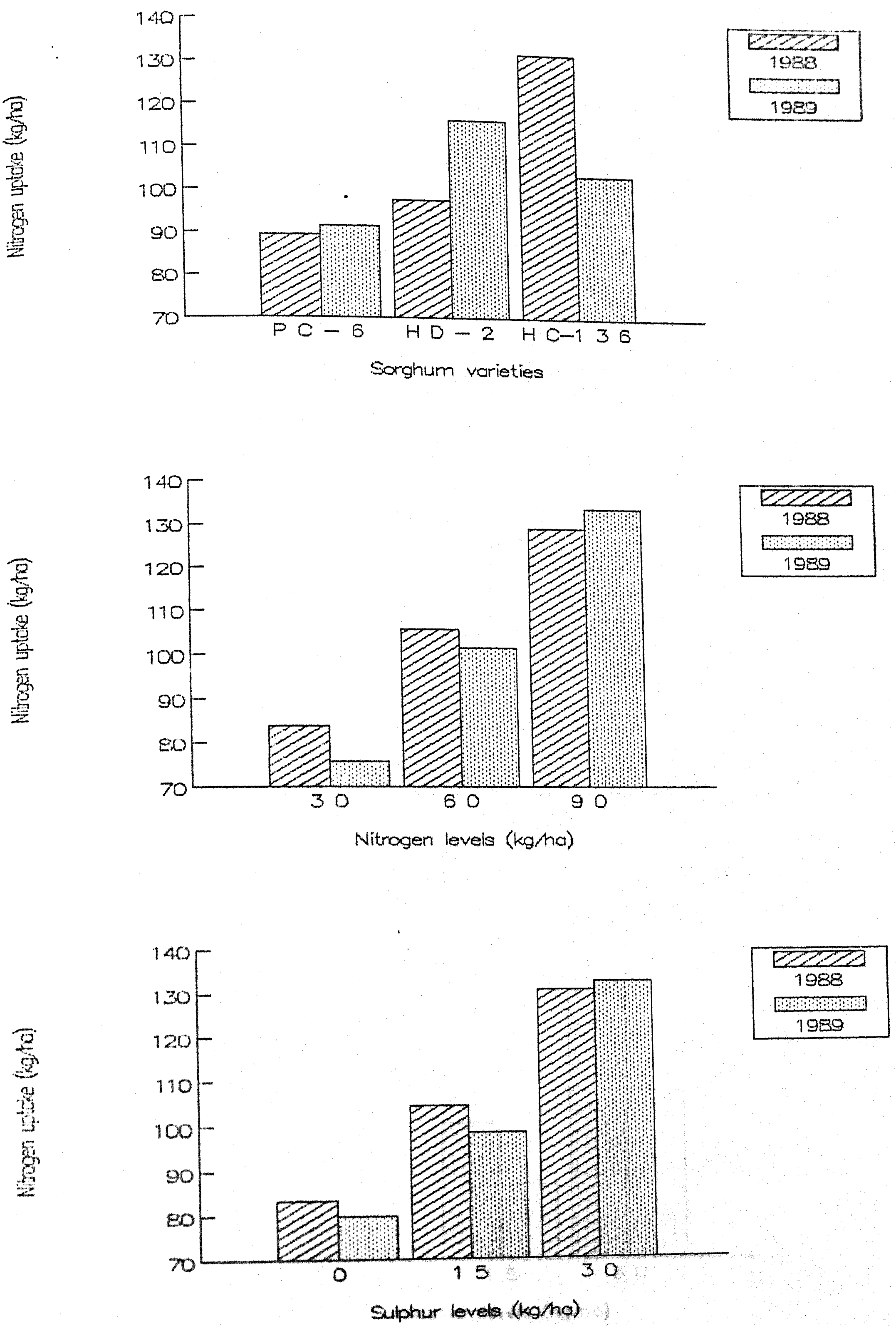
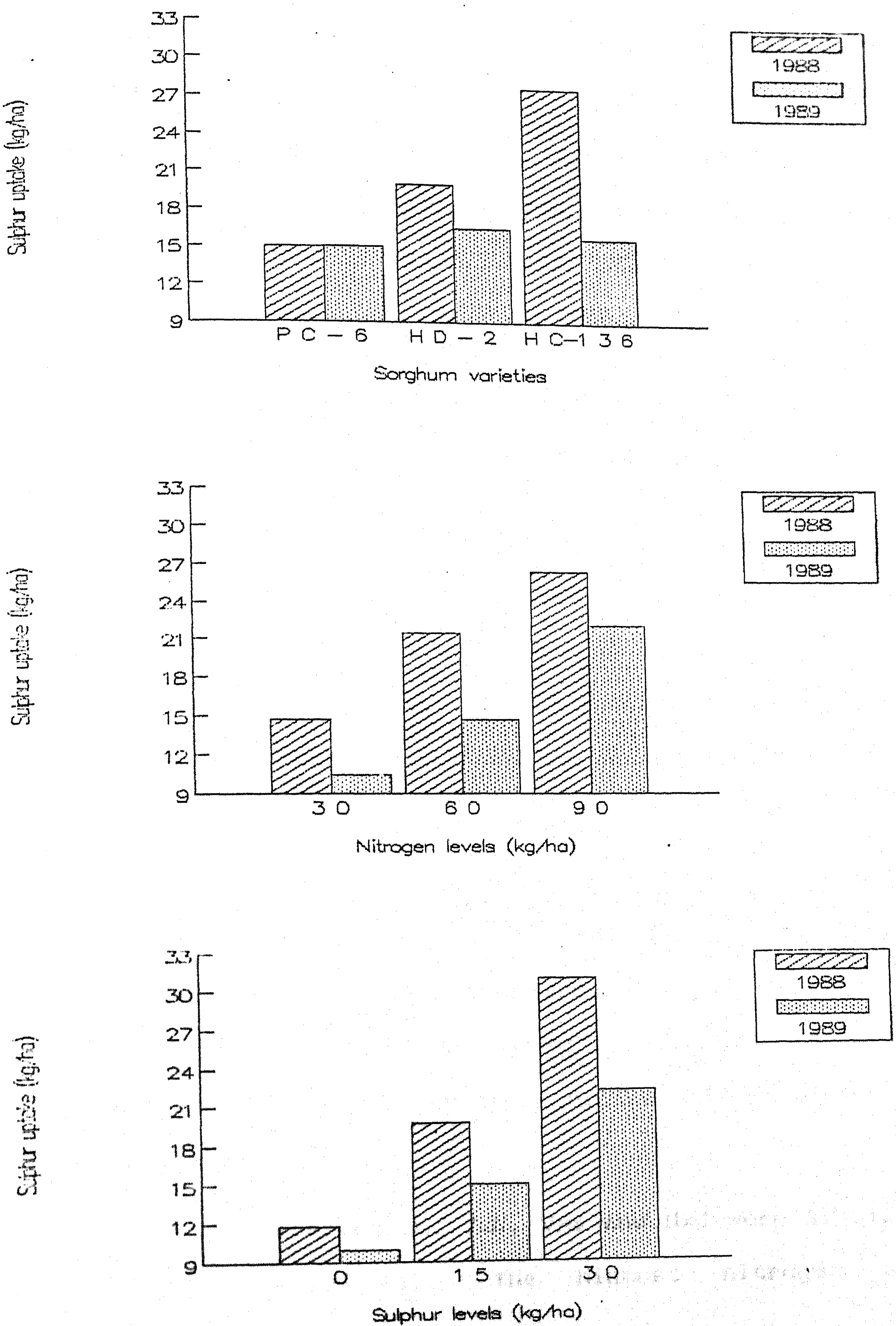


FIG 34: SULPHUR UPTAKE (kg/ha)



Nitrogen uptake:

A perusal of the data revealed that the average uptake of nitrogen was 106.2 kg/ha in 1988 and 103.7 kg/ha in 1989.

The sorghum varieties differed significantly in nitrogen uptake in both the years. Variety HC-136 resulted in significantly highest nitrogen uptake (131.9 kg/ha) as compared to HD-2 and PC-6 in 1988. In 1989, however, significantly highest uptake of nitrogen occurred with HD-2 (116.3 kg/ha). Variety PC-6 caused lowest uptake of nitrogen in both the years.

The nitrogen uptake increased significantly due to increasing doses of nitrogen in both the years. The differences between 30 and 60 as well as between 60 and 90 kg N/ha were significant. Thus, application of 30 to 90 kg N/ha increased the average nitrogen uptake from 79.2 to 131.5 kg/ha.

The sulphur nutrition also caused significant variation in nitrogen uptake in both the years. There was a significant difference in nitrogen uptake when sulphur was increased from 15 to 30 kg S/ha. Both these doses caused significantly greater uptake of nitrogen over control treatment.

The interactions VxN, VxS and NxS were significant in 1989 (Table 43). The highest nitrogen uptake

Table 43. Effect of VxN, VxS and NxS interactions on nitrogen uptake (kg/ha) in 1989.

Nitrogen (kg/ha)	Varieties			Sulphur (kg/ha)	Varieties			Nitrogen (kg/ha)		
	PC-6	HD-2	HC-136		PC-6	HD-2	HC-136	30	60	90
30	69.67	80.32	77.02	0	76.65	83.61	78.86	61.50	78.03	99.59
60	81.15	122.08	101.39	15	88.22	107.78	99.80	72.68	98.16	124.96
90	122.75	146.54	132.37	30	108.69	157.55	132.11	92.82	128.42	177.10

SEm ± 3.166

CD at 5% 10.32

(146.54 kg/ha) occurred when variety HD-2 was fertilized with 90 kg N/ha. This was followed by variety HC-136 at the same dose of nitrogen. Variety HD-2 fertilized with 30 kg S/ha caused significantly higher uptake of nitrogen (157.55 kg/ha) as compared to other combinations. Variety HC-136 receiving 30 kg S/ha appeared to be next best combination.

The perusal of the data on significant NxS interaction clearly demonstrated that the highest nitrogen uptake occurred when crop received 90 kg N and 30 kg S/ha. The combinations of 90 kg N + 15 kg S/ha and 60 kg N + 30 kg S/ha were at par in so far as the uptake of nitrogen was concerned.

Sulphur uptake:

The average uptake of sulphur was 20.87 kg/ha in 1988 against 15.74 kg/ha in 1989. Varietal differences in respect of sulphur uptake was significant in 1988. Variety HC-136 resulted in significantly greater uptake of sulphur as compared to HD-2 and PC-6 which also differed between themselves. In 1989, however, there was no significant variation in sulphur uptake of different varieties.

The difference in sulphur uptake due to nitrogen applicatioln was found to be signficant. In 1988, application of 60 and 90 kg N/ha caused similar uptake of sulphur but significantly greater than 30 kg N/ha. In 1989

however, the successive differences in sulphur uptake with increasing levels of nitrogen from 30 to 90 kg N/ha were significant.

Sulphur nutrition exercised significant effect on its uptake in both the years. The application of 15 and 30 kg S/ha differed significantly between themselves and proved statistically superior over control in this regard.

The nitrogen and sulphur levels interacted significantly in influencing the sulphur uptake (Table 44). Application of 90 kg N and 30 kg S/ha caused significantly greater uptake of sulphur (32.3 kg/ha) as compared to other fertilizer combinations. The use of 90 kg N with 15 kg S/ha was at par with 60 kg N and 30 kg S/ha in sulphur uptake.

Table 44. Effect of NxS interaction on sulphur uptake (kg/ha) in 1989.

Sulphur (kg/ha)	Nitrogen (kg/ha)		
	30	60	90
0	6.12	9.91	13.93
15	11.01	13.86	20.05
30	14.08	20.34	32.31

SEm $\pm$ 1.069

CD at 5% 3.49

Response functions:

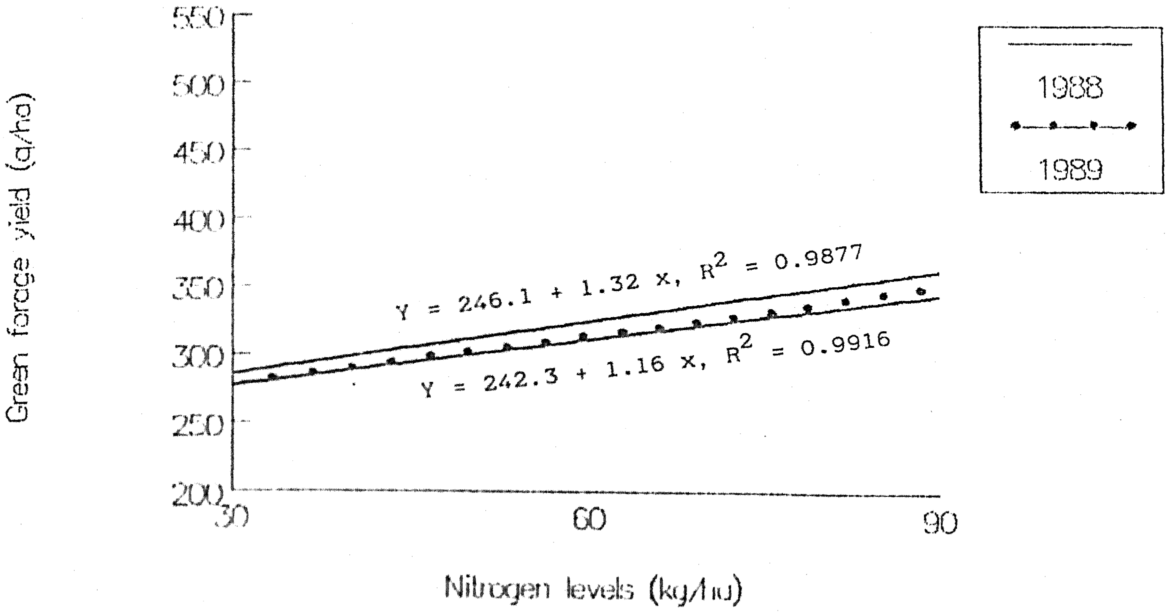
In order to study the response behaviour of sorghum varieties to varying levels of nitrogen and sulphur, the response equations were fitted both for green and dry matter yields for individual variety. The single degree analysis was done to find out the nature of response functions. The nature of response to nitrogen and sulphur are enumerated herewith.

Nitrogen: The response curves alongwith equations and degree of correlations (R^2) for green and dry matter yields of sorghum varieties are set out in Fig. 35 to 37. A perusal of the observations indicated that the response to nitrogen both in terms of green forage production and dry matter accumulation was linear for all the three sorghum varieties. The degree of correlation measured as value of R^2 was maximum for variety HD-2 (0.9995 for green matter and 0.9999 for dry matter) in 1988. The values of R^2 for variety HC-136 were lowest in the same year both for green forage (0.9350) and dry matter (0.9702) yields. PC-6 on the other, showed intermediate R^2 values.

The response to per kg applied nitrogen varied from variety to variety and the degree of response decreased with increasing doses of fertilizer nitrogen in all the varieties (Table 45). In case of variety PC-6 the green forage yield per kg of applied N decreased from 9.44 to 4.02 q/ha when nitrogen was increased from 30 to 90 kg/ha

FIG 35:RESPONSE FUNCTION FOR N(PC-6)

GREEN FORAGE YIELD



DRY MATTER YIELD

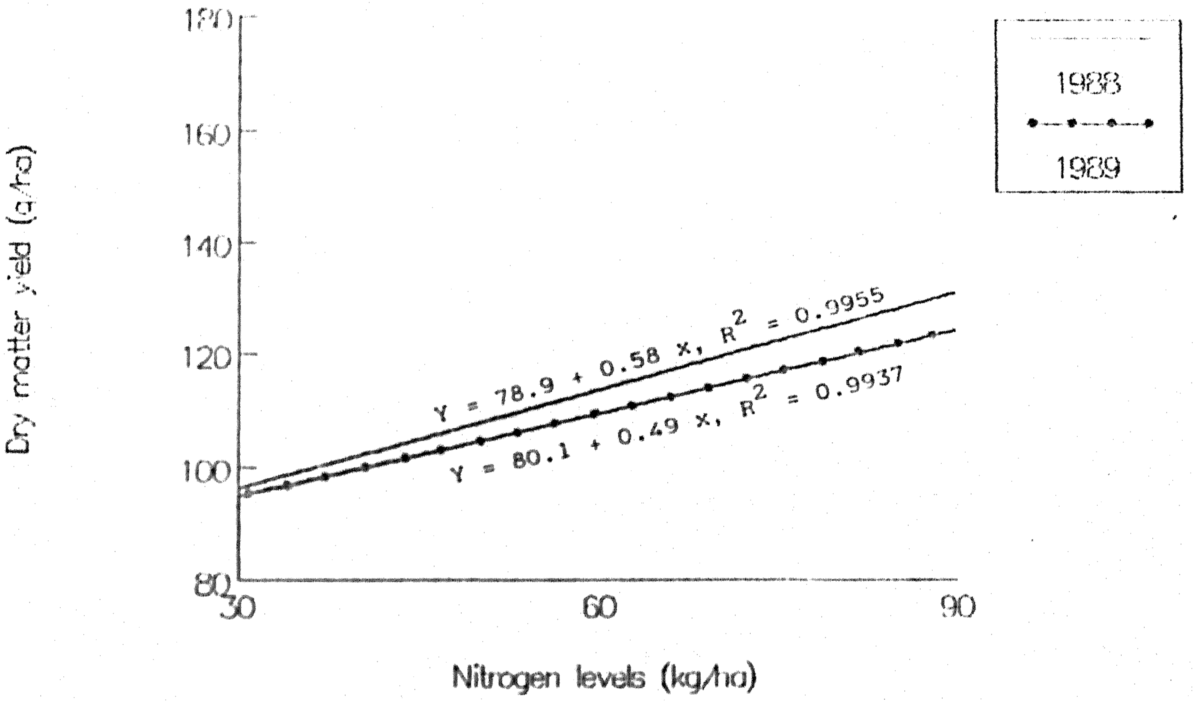
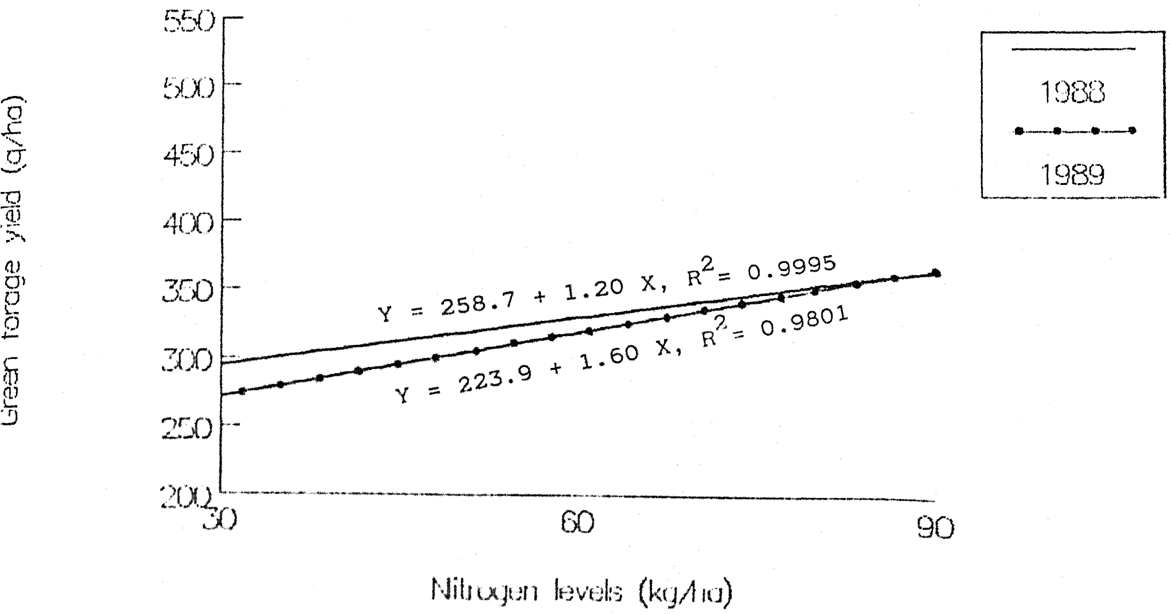


FIG 36:RESPONSE FUNCTION FOR N(HD-2)

GREEN FORAGE YIELD



DRY MATTER YIELD

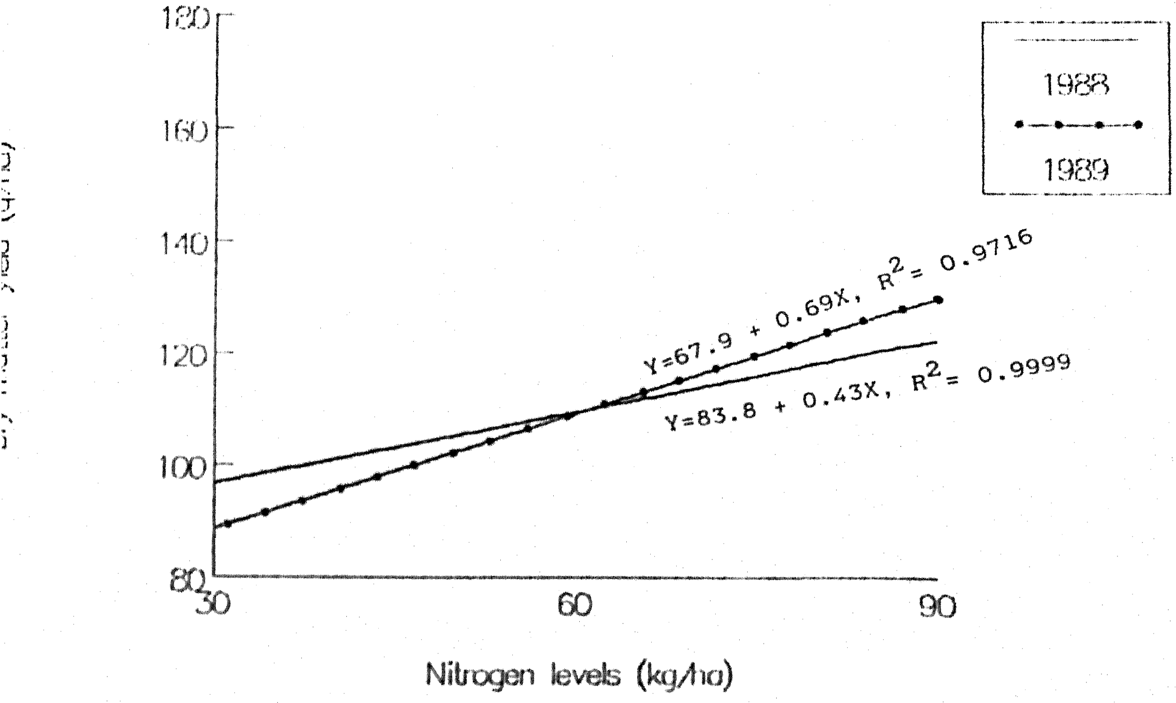
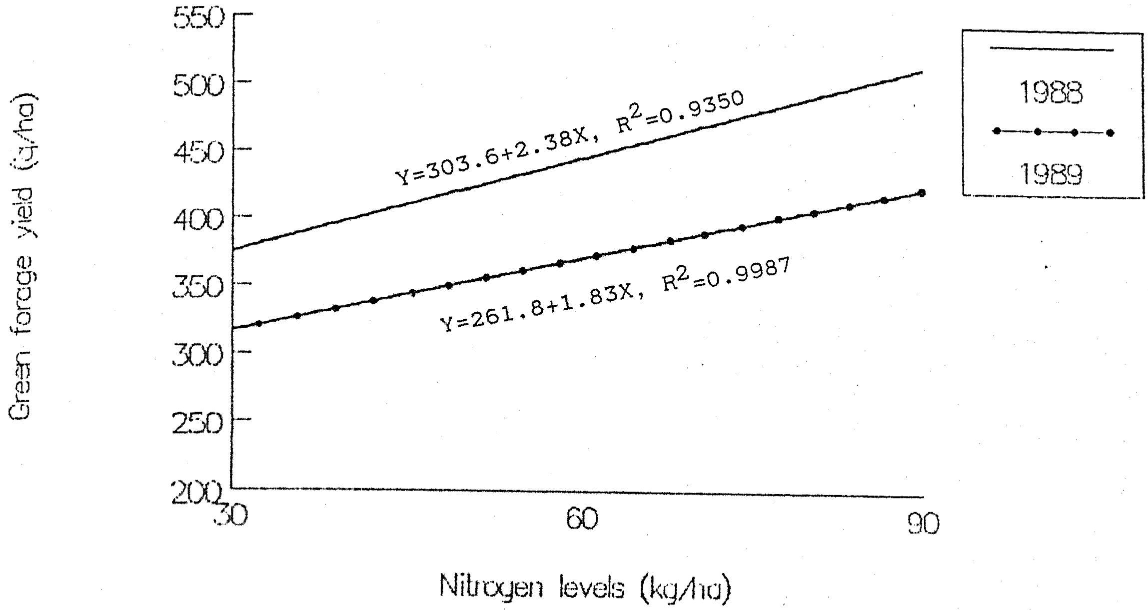


FIG 37:RESPONSE FUNCTION FOR N(HC-136)

GREEN FORAGE YIELD



DRY MATTER YIELD

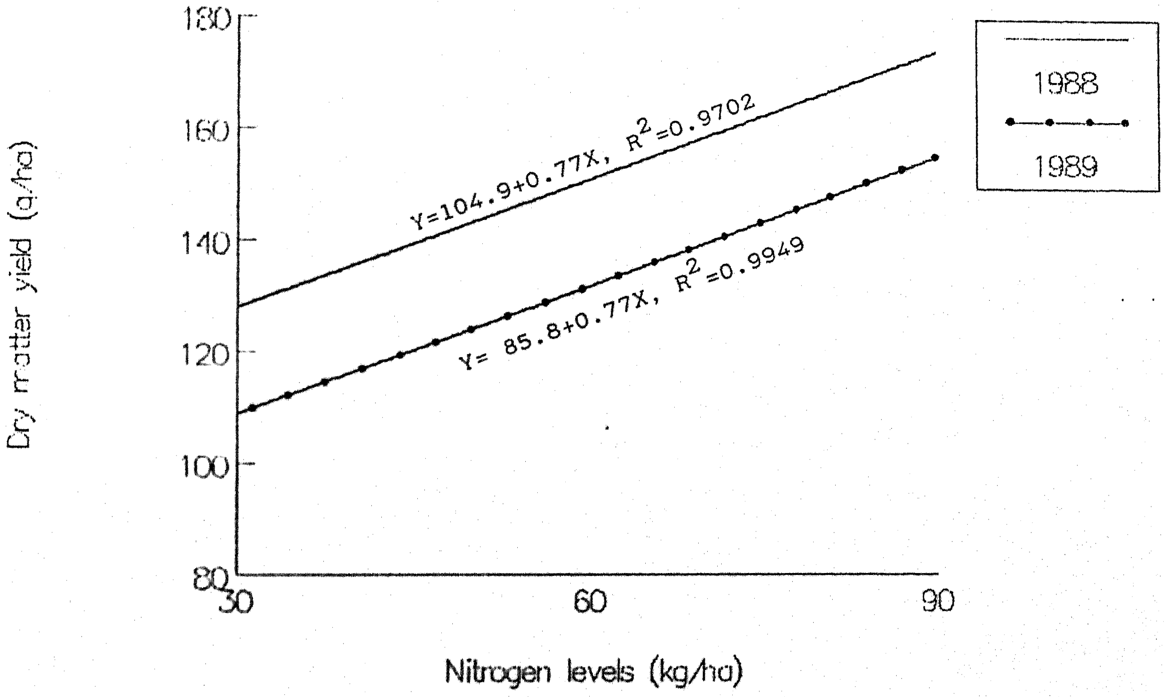


Table 45. Response to per kg of applied nutrients (q/ha)

Applied nutrient (kg/ha)		PC-6		HD-2		HC-136	
		1988	1989	1988	1989	1988	1989
Green forage							
Nitrogen	30	9.44	9.30	9.80	8.94	12.86	10.61
	60	5.51	5.14	5.54	5.46	7.08	6.15
	90	4.03	3.87	4.07	4.03	5.88	4.75
Sulphur	15	21.94	20.43	22.21	21.49	29.43	25.10
	30	12.22	11.19	11.57	12.13	16.01	13.69
Dry matter							
Nitrogen	30	3.17	3.19	3.22	2.89	4.34	3.61
	60	1.94	1.81	1.83	1.90	2.44	2.21
	90	1.45	1.39	1.36	1.43	1.96	1.72
Sulphur	15	7.77	7.17	7.22	7.27	9.75	8.89
	30	4.24	4.05	3.95	4.36	5.47	5.03

in 1988. Such decrease was from 9.30 to 3.87 q/ha in 1989. The corresponding responses in terms of dry matter production worked out to be 3.17 to 1.45 q/ha in 1988 and 3.19 to 1.39 q/ha in 1989.

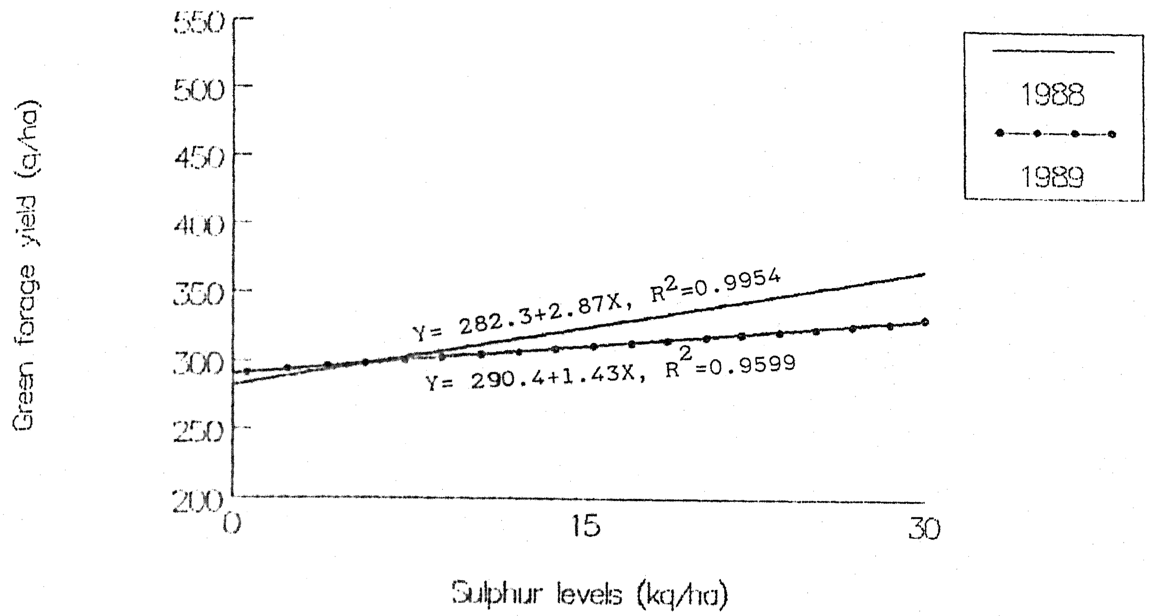
The level of response to increasing doses of nitrogen from 30 to 90 kg N/ha with variety HD-2 decreased from 9.80 to 4.07 q/ha in 1988 and from 8.94 to 4.03 q/ha in 1989 in terms of green forage yield. The decrease in degree of response in terms of dry matter accumulation was 3.22 to 1.36 q/ha in 1988 and from 2.89 to 1.43 q/ha in 1989.

Though, the level of response to each kg of fertilizer nitrogen was the highest with variety HC-136, but it decreased from 12.86 to 5.88 in 1988 and from 10.61 to 4.75 q/ha green forage in 1989 with increase in nitrogen dose from 30 to 90 kg/ha. The corresponding decreases in terms of dry matter production were from 4.34 to 1.96 q/ha in 1988 and from 3.61 to 1.72 q/ha in 1989. These observations, therefore, indicate that the level of response to each kg of fertilizer nitrogen remained less than half at 90 kg N/ha as compared to 30 kg N/ha with all the varieties.

<u>Sulphur</u>: The response curves and equations for sulphur are depicted in Fig. 38 to 40. It is evident that the response to sulphur was also linear for green forage and dry matter yields in both the years.

FIG 38:RESPONSE FUNCTION FOR S(PC-6)

GREEN FORAGE YIELD



DRY MATTER YIELD

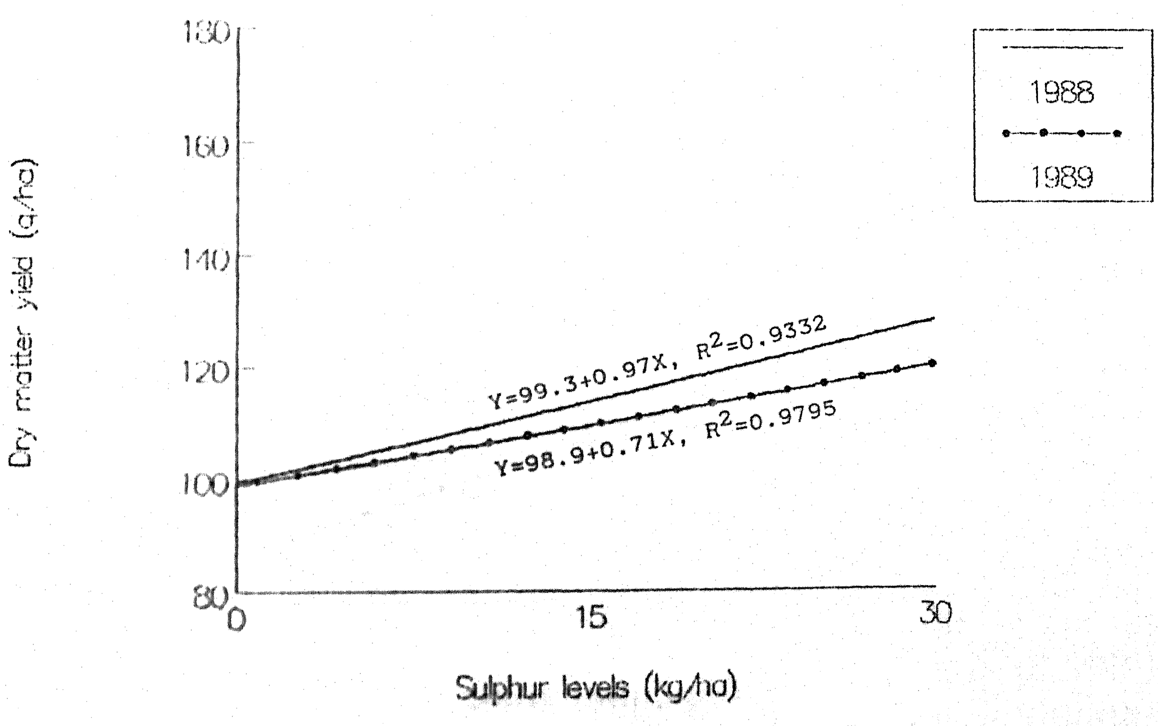
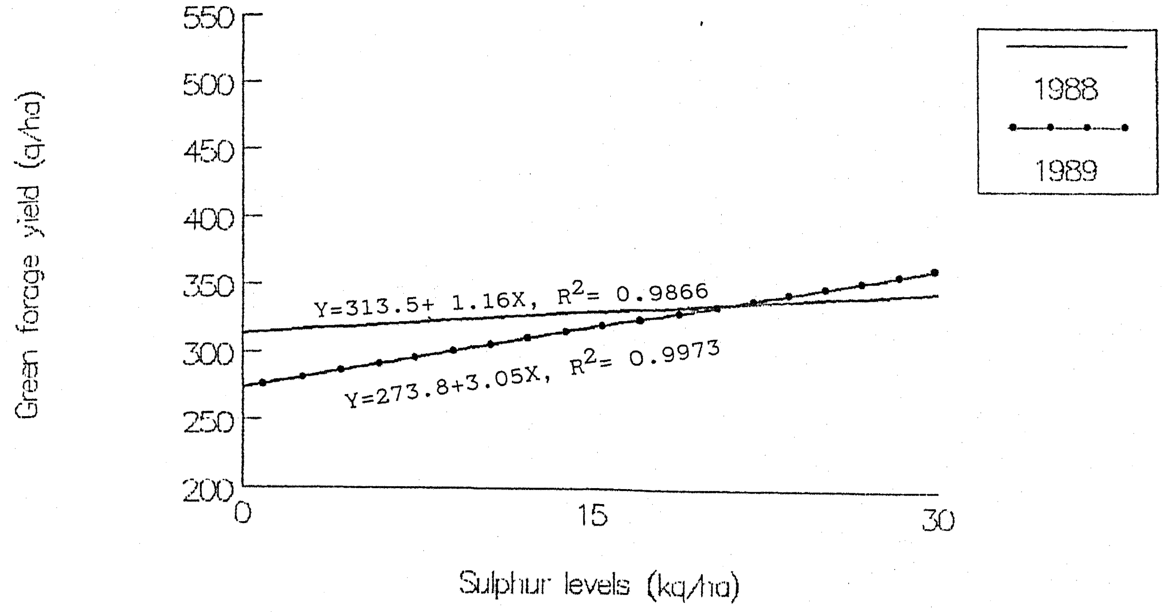


FIG 39:RESPONSE FUNCTION FOR S(HD-2)

GREEN FORAGE YIELD



DRY MATTER YIELD

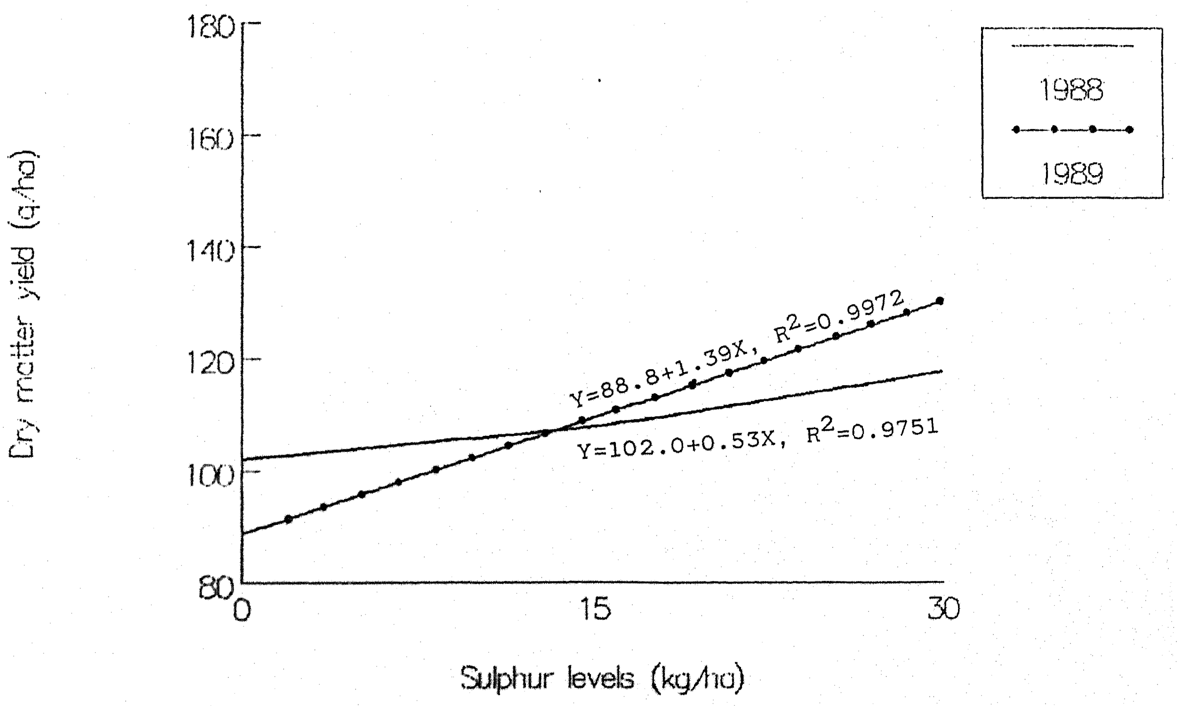
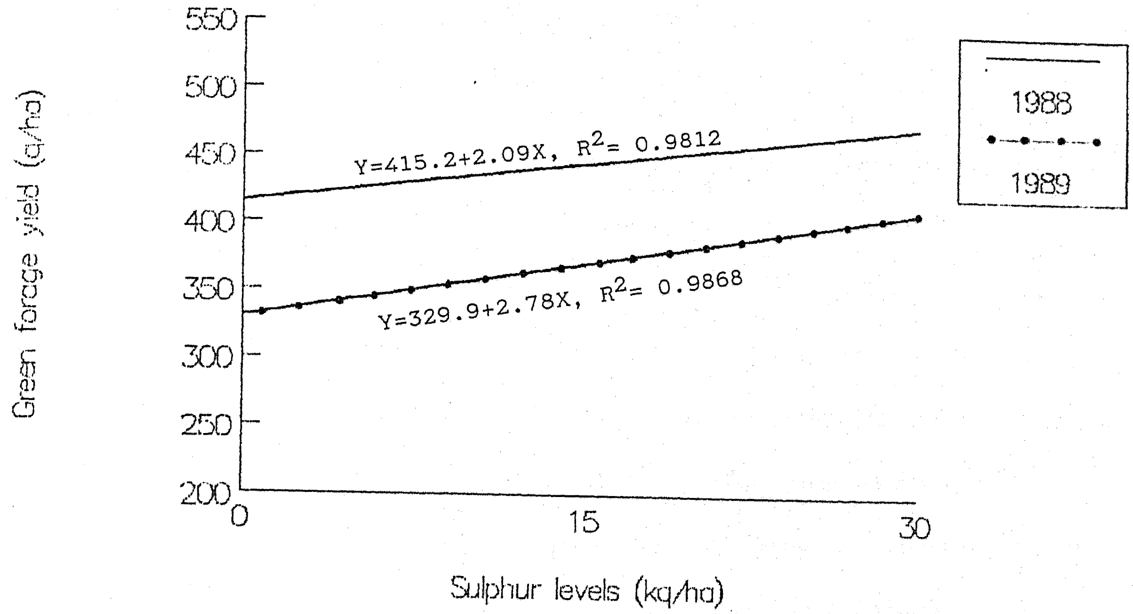
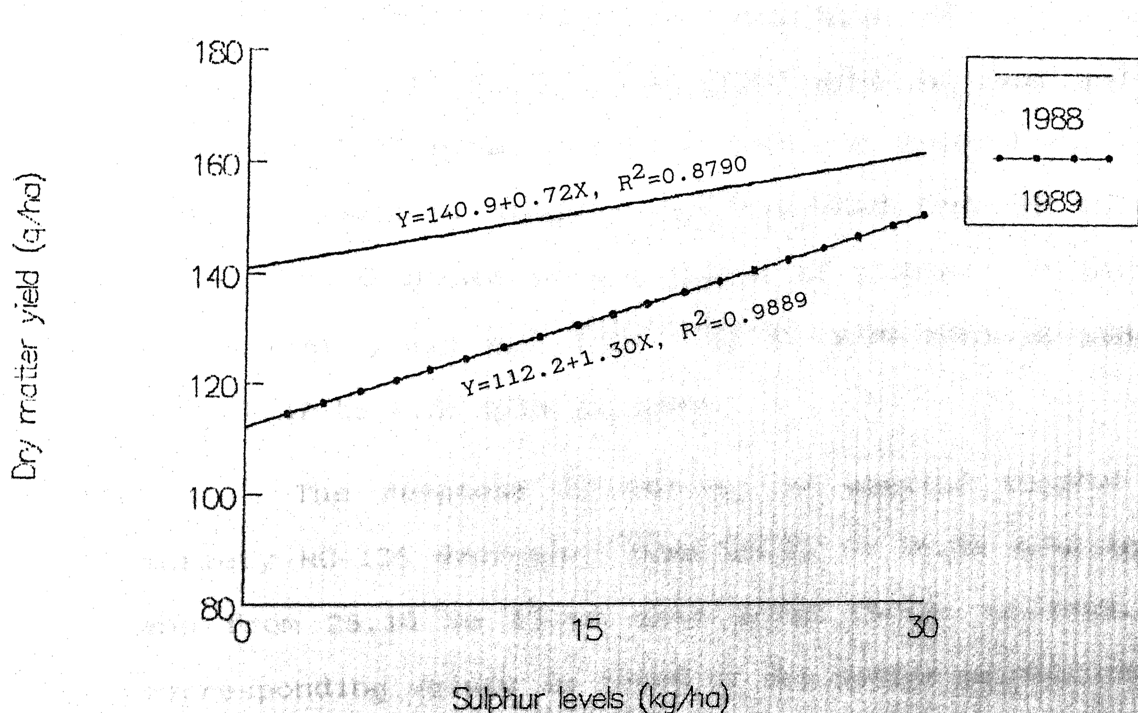


FIG 40:RESPONSE FUNCTION FOR S(HC-136)

GREEN FORAGE YIELD



DRY MATTER YIELD



The highest values of R^2 were observed for variety HD-2 in 1989 for green forage (0.9973) and dry matter (0.9972) yields. The lowest R^2 values were observed for HC-136 in 1988 both for green forage production (0.9812) and dry matter accumulation (0.8790).

Similar to nitrogen, the increasing doses of sulphur decreased the magnitude of response to each kg of applied sulphur and the level of response varied with varieties (Table 45). In case of variety PC-6 the response to per kg of applied sulphur at 15 and 30 kg S/ha decreased from 21.94 to 12.22 q/ha in 1988 and from 20.43 to 11.19 q/ha in 1989 in terms of green forage yield. The corresponding decreases in dry matter yields were from 7.77 to 4.24 q/ha in 1988 and from 7.17 to 4.05 q/ha in 1989.

In case of HD-2 the reduction in the level of response was from 22.21 to 11.57 q/ha in 1988 and from 21.49 to 12.13 q/ha in 1989 in terms of green forage yield when the dose of sulphur was increased from 15 to 30 kg S/ha. The decrease in the degree of response in terms of dry matter yield was from 7.22 to 3.95 q/ha in 1988 and from 7.27 to 4.36 q/ha in 1989.

The response to per kg of applied sulphur with variety HC-136 decreased from 29.43 to 16.01 q/ha in 1988 and from 25.10 to 13.69 q/ha green forage in 1989. The corresponding values in terms of dry matter production were 9.75 to 5.47 q/ha in 1988 and from 8.89 to 5.03 q/ha in 1989.

D I S C U S S I O N

DISCUSSION

Growth and forage yield of sorghum varieties in relation to weather conditions:

The forage production per unit area is a resultant of the interactions between genotypes and environment. The environmental factors influence the morphological (structural) and physiological (functional) responses of plants in a coordinated manner to determine the level of crop yield. In the present investigation the green forage yield and dry matter production of all the sorghum varieties was higher in 1988 as compared to 1989 (Table 11 and Fig. 10 & 11) indicating that the weather conditions exhibited a strong bearing on the growth performance of the crop resulting in appreciable yield variations over the years. Though the total rainfall during the crop season was higher in 1989 (634.3 mm) as compared to 1988 (556.3 mm) but its distribution was better in 1988. These rains were received in 35 rainy days in 1988 against in 21 days in 1989 indicating that rains were more intense during second year which were not congenial for sorghum crop. The year 1988 faced one week's drought from September 3 to 9 coinciding with 55 to 62 days of crop growth when varieties HD-2 and PC-6 had already completed their grand vegetative growth.

On the contrary the year 1989 faced two critical dry spells each of the two weeks duration coinciding with establishment (3 to 17 days of crop stage) and active vegetative growth period (45 to 59 days of crop growth). Thus in 1989 the crop suffered due to prolonged moisture stress at critical physiological stages which caused reduction in forage yield. Moreover, the maximum and minimum temperatures from standard week Nos. 29 to 32 remained higher in 1989 as compared to year 1988. This coincided with the period after germination in 1988 but right from the germination in 1989 which might have adversely affected seedling vigour and establishment in latter year and consequently upon growth attributes. Thus in 1988 the crop experienced cordinal temperature points upto grand vegetative growth phase because the minimum, optimum and maximum temperatures for sorghum have been reported as 10, 31.7 and 40°C respectively (Morachan, 1978). The growth characters like plant height, number of functional leaves, length and breadth of leaves and leaf area were higher in 1988 as compared to that in 1989. The effect of greater moisture stress in 1989 was finally reflected in lower relative leaf turgidity (80.1%) as compared to 1988 (86.0%). Similarly, the plant water stress measured in terms of difference between canopy and atmospheric temperatures (Tc-Ta) during critical dry spells was also of higher order in the year 1989.

Growth and forage productivity of sorghum varieties:

Sorghum variety HC-136 exhibited better growth performance and significantly out yielded PC-6 and HD-2 in green forage production and dry matter accumulation in both the years of investigation. Taller plants with greater number of broader functional leaves (Table 3 & 5 and Fig. 3, 4 & 6) attributed to higher forage production in this variety. Higher production potential of HC-136 as compared to other cultivars has also been reported by Lodhi and Grewal (1988), Lodhi and Chowdhury (1988) and Hazra (1989). Shinde et al. (1987) also found that Haryana Chari (HC-136) out yielded Pusa Chari-6 and M.P. Chari in fresh fodder yield. The varietal characteristics of HC-136 relate to its tall plant height, sweet, juicy stem, greater number of leaves and longer leaf area duration (leaves remain green upto maturity stage). All these growth attributes make it an excellent forage type for extended period of herbage availability.

In terms of green and dry matter productivity per day, however, variety HD-2 excelled PC-6 and HC-136. This is attributed to its earliness as it attained flowering stage in 70 days against 85 and 100 days taken by PC-6 and HC-136, respectively. Thus to reach at the same physiological stage, PC-6 takes 15 days more and HC-136 takes 30 days more over HD-2 indicating that HD-2 lends itself for fitting in cropping systems more flexible than

PC-6 and HC-136. Moreover, on account of short duration HD-2 escapes the period of moisture stress during post monsoon period.

Effect of nitrogen nutrition on growth and forage yield:

The increasing doses of nitrogen from 30 to 90 kg N/ha significantly increased the green and dry matter production in both the years with the result that the highest forage yield was obtained at 90 kg N/ha (Table 11 and Fig. 10 & 11). The positive effect of nitrogen nutrition in enhancing the green and dry matter yields is associated with an increase in growth attributes such as plant height, number of functional leaves, length, breadth and area of leaves (Table 3, 5, 6 and Fig. 3 to 7). This is because of the fact that nitrogen is involved in increasing the protoplasmic constituents and accelerating the processes of cell division and alongation which in turn give luxuriant vegetative growth for high tonnage productivity (Watson, 1952). This is also substantiated by the data on relative leaf turgidity which increased with increasing levels of nitrogen from 30 to 90 kg N/ha.

Tregubenke and Filippov (1966) found an increase in the amount of most strongly bound water and water potential of leaf cells by increasing the nitrogen-phosphorus nutrition. Nitrogen nutrition induces an enhancement in the water retaining forces of the cell and reduces the rate of transpiration in the leaves and ultimately stimulates

growth, resulting in better crop yield. Singh (1980) also reported that nitrogen enhances the growth and yield of maize plants by stimulating various metabolic processes. The favourable effects of nitrogen on growth attributes (plant height and number of leaves), palatability characteristics (leaf : stem ratio), quality parameters (protein and fat) and herbage yield of sorghum have been reported by Bajwa et al. (1983) and El-Kassaby (1985).

Effect of sulphur nutrition on growth and forage yield:

Application of 15 and 30 kg S/ha brought out significant improvement in forage production in both the years except in terms of dry matter yield in 1988 where 15 kg S/ha did not exhibit variation over control treatment. The favourable influence of sulphur is due to its resemblance with nitrogen in its role and function in plant metabolism. This is substantiated with the fact that the requirement of nitrogen and sulphur in protein moiety is in the ratio of 15:1 meaning thereby that the lack of sulphur would hinder the protein synthesis even if the plants are adequately supplied with nitrogen. Sulphur, in the form of sulphate, is essential for all plants and it is indispensable for the syntghesis of certain amino acids like methionine, cystine and cysteine. Besides, sulphur is involved in various metabolic and enzymic progresses of plants. It is also a constituent of glutathione, a compound supposed to play a part in plant respiration and

in the synthesis of essential oils. Further, sulphur also plays a vital role in chlorophyll formation (Goswami, 1988). Its role as plant nutrient for correcting S deficiency, increasing crop yield and improving the quality of produce has been well documented (Kanwar and Mudakar, 1985). Though the effect of 15 kg S/ha was not so conspicuous but 30 kg S/ha tangibly enhanced the growth attributes particularly plant height, length, breadth and area of functional leaves in sorghum varieties which reflected over all improvement in herbage yield.

The significant N x S interaction for green forage and dry matter yields in 1989 (Table 13 & 14) indicates that in view of the close metabolic association between nitrogen and sulphur the relationship between them is synergistic. Since these nutrients enhance the concentration and uptake of each nutrients enhance the concentration and uptake of each other, their effects are positively reflected in crop productivity. The observation that fertilizer schedule of 90 kg N + 15 kg S/ha produced dry matter yield similar to that obtained with 60 kg N + 30 kg S/ha suggests that an additional dose of 15 kg S/ha saves 30 kg N/ha. In other-words, each kg of S yields dry matter equivalent to 2 kg of N. Tripathi and Hazra (1988) also observed that 60 kg N + 40 kg S/ha increased the forage yield of chinese cabbage significantly. However, in some other studies, the NxS interaction did not bring out significant effect on forage

yield of sorghum on sandy loam soil (Singh and Singh, 1987) and silage maize on sandy as well as silt loam soils (D'Leany and Rehm, 1990). These findings therefore, indicate that edaphic conditions greatly influence the degree of interactions between nitrogen and sulphur.

The V x N and V x S interactions for green forage and dry matter yields in 1989 (Table 13 & 14) was significant. Variety HC-136 with 60 kg N/ha produced similar dry matter as HD-2 with 90 kg N/ha. Similarly the dry matter yield of HC-136 with 15 kg S/ha was at par with that of HD-2 with 30 kg S/ha. These observations therefore, suggest that variety HC-136 has the potential to produce higher dry matter at low level of N or S and also responsive to high level of fertilizer inputs.

Effect of treatment variables on quality traits:

Crude protein: The crude protein content in all the sorghum varieties decreased gradually with the advancement in crop age (Table 19 & 20 and Fig. 15 to 17). This is because of the fact that crop accumulates greater dry matter and fibre fractions with the crop growth stages. These processes coupled with greater degree of lignification cause gradual decrease in crude protein content (Rekib *et al.*, 1979; Devasenapathy and Subburayalu, 1986; and Khandaker and Islam, 1988). Among sorghum varieties HD-2 invariably maintained comparatively higher level of protein content upto 55 days of growth in 1989 due

to shorter span of growth period. This was followed by PC-6 upto 40 days and by HC-136 at 55 days which could be attributed to higher leaf : stem ratio in former and longer leaf area duration in latter one.

Nitrogen nutrition exercised a positive influence on protein content of sorghum varieties at all the stages of growth. Thus, increasing doses of nitrogen from 30 to 90 kg N/ha caused progressive increase in protein content. This is attributed to the involvement of nitrogen in the synthesis of aminoacids and accumulation of protein moiety in plants. Considerable evidences are available to show the key role of fertilizer nitrogen in increasing the crude protein content and forage quality (Oberoi, 1980; Menhi Lal and Tripathi, 1987 and Mannikar, 1980).

There was a distinct improvement in crude protein content at various crop growth stages due to sulphur nutrition at 15 and 30 kg S/ha. The vital role of S in protein formation might be due to its being constituent of few amino acids (cystine, cysteine and methionine) which are essential for biosynthesis of protein (Aulakh and Dev, 1978; Goswami, 1988).

The beneficial effects of sulphur fertilization on protein content of various forage crops have also been reported by Pasricha and Randhawa (1975), Singh et al. (1983) and Tripathi and Hazra (1988).

<u>Water soluble carbohydrates</u>: The water soluble carbohydrates content in sorghum varieties progressively increased upto 70 days of growth in both the years. Thereafter the trend was variable. This indicates that the level of water soluble carbohydrates in plants is associated with its physiological growth stages and the higher content was observed when plants entered into reproductive phase. This is further substantiated by the fact that protein content dropped continuously upto 70 days of growth which is inversely related with carbohydrates content (Thakare, 1987). Mohammed and Hamid (1988) also found the highest nonstructural carbohydrates content at soft dough stage. The subsequent decrease at 85 DAS in PC-6 and HC-136 is attributed to the redistribution of photosynthates in the entire biomass. In general, variety HC-136 maintained higher water soluble carbohydrates as compared to other varieties at various stages of growth except HD-2 at 70 days (harvesting stage) in 1989. This suggests that variety HC-136 is photosynthetically more active throughout its growth period which is of course evident from the fact that it remains green upto maturity stage. The higher water soluble carbohydrates content in HC-136 has been reported as its varietal characteristics by Lodhi and Chowdhury (1988) and Lodhi and Grewal (1988).

Both nitrogen and sulphur nutrition individually and in combination increased water soluble carbohydrates

content in sorghum varieties. This is attributed to the involvement of N in photosynthesis (Singh, 1980) and of S in chlorophyll formation (Goswami, 1988). Sulphur application increases soluble sugars due to acceleration of photosynthesis by improving leaf area, enhancing CO_2 fixation into glucose, fructose and sucrose and nitrogen metabolism (Jones et al.,1970; Zaroug and Munns, 1980 a). Similarly, increasing level of sulphur in the rooting medium drastically reduces the amide N and markedly increases the soluble sugar content in young corn plants (Tisdale, 1977).

Hydrocyanic acid: The HCN content decreased with the advancement in crop age and the reduction was more conspicuous beyond 55 days in both the years (Table 30a & 31a and Fig. 21 to 23). Young tissues frequently contain high levels of glycosides the precursor of HCN which decreases with the age of the plants (Chatterjee and Das, 1989). This is associated with reduced activity of metabolic enzyme beta-glucosidase, hydrolysing dhurrin into HCN at advanced stages of plant growth. The distribution of initially synthesized glucosides over the increased accumulated dry matter further reduces its concentration in plants. As such the hydrogen cyanide potential of sorghum after flowering may be only 10% of its value when young and vegetative (Wheeler and Mulcahy, 1989). Therefore, the crop should preferably be harvested after flowering but never before 40 to 50 days from the date of sowing.

Sorghum variety PC-6 exhibited lower content of HCN than other cultivars particularly during first 40 days in 1988 and 55 days in 1989. HD-2 on the other hand, contained higher HCN content throughout. It has been established that apart from environmental conditions, age and genotypes have in field grown crops, the most substantial effect on HCN potential.

Increasing doses of nitrogen caused a significant increase in HCN content particularly during vegetative stages of growth (upto 55 DAS). The effect was more pronounced in 1989 at 25 DAS when crop faced soil moisture stress following germination stage due to critical dry spell of two weeks. Under such conditions, the triggering effect of increased nitrogen dose from 60 to 90 kg/ha on HCN concentration was more pronounced than its increase from 30 to 60 kg/ha. High nitrogen availability and wilting can increase HCN concentration by 20-40% and both these factors appear liable to interact positively. In water deficit condition, it increases and during drought the plants are stunted and the cyanide content is high. So drought wilted young plants should never be fed to cattle. The increase in nitrogen from 0 to 90 kg/ha on an average increased HCN content in sorghum from 215.0 to 345.6 ppm (Taneja et al., 1983) and from 2.9 to 5.4 mg/100 g dry matter when nitrogen increased from 40 to 100 kg/ha (Raj and Patel, 1988).

Sulphur nutrition caused significant reduction in HCN content of sorghum plants at all the stages of growth and the effect was more pronounced in 1989 at initial stages of growth (25 DAS) when crop experienced recurrent critical dry spells. The application of sulphur has been found to reduce the HCN content in sorghum (Shaik and Zende, 1972; Shukla et al., 1973; Singh et al., 1983) and tapioca (Mohankumar and Nair, 1983). The possible mechanism is associated with its role in maintaining greater relative leaf turgidity which mitigates the effect of moisture stress in so far as the HCN accumulation in plants is concerned. This is also substantiated by the fact that leaves contain higher amount of glucoside than the stems. Further, variety PC-6 fertilized with low level of N or high level of S (30 kg/ha each) exhibited lowest HCN concentration at critical stages whereas HD-2 showed highest HCN accumulation. It justifies the statement that environment, nutritional status and genotype greatly influence the level of HCN toxicity. Limited supply of nitrogen or adequate sulphur nutrition reduces the level of HCN toxicity (Chatterjee and Das, 1989).

Fibre fractions: Crude fibre represents the frame work of the plants and includes cellulose, hemicellulose and lignin fractions of the cell wall. Neutral detergent fibre (NDF) is an estimate of cell wall content and acid detergent fibre (ADF) is actually a measure of lignocellulose complex in the forage materials. Sorghum variety HC-136 contained

lowest percentage of most of the fibre fractions (NDF, ADF,cellulose and lignin) indicating that this particular variety does not become too fibrous even at flowering stage (Table 35, 37 & 38 and Fig. 24 to 26 & 28). In otherwords, it maintains its desirable characteristics of higher intake and digestibility.

Nitrogen nutrition had no consistent and significant effect on fibre fractions. However, relatively lower ADF content was observed with 30 kg N/ha. The NDF content either remained constant or increased marginally with increasing dose of nitrogen from 30 to 60 kg N/ha. The lowest cellulose content was observed with 90 kg N/ha in both the years. In general, hemicellulose content increased with increasing nitrogen levels. The lowest lignin content was observed at 30 kg N/ha. The decrease in cellulose content with increasing nitrogen levels corroborates with the findings of Mohammed and Hamid (1988).

Sulphur nutrition also did not exercise any significant effect on fibre fractions of sorghum and the response was variable. However, increasing doses of sulphur from 0 to 30 kg S/ha decreased the lignin content of plants. O'Leany and Rehm (1990) also observed that neither N nor S had a significant effect on ADF and NDF contents of silage maize.

Nitrogen and sulphur contents, N : S ratio and their uptake in plants:

On an average variety HD-2 not only recorded higher N and S contents but also maintained wider N : S ratio (Table 39 & 40 and Fig. 30 to 32). This is attributed to its early bulking nature which necessitates rapid uptake of these nutrients. Moreover, the absorption of N and S is more vigorous at the early stages of growth to meet the need of metabolic processes (Joshi and Prasad, 1979) which is also substantiated by high protein content of this variety at initial stages of growth. The total uptake of N and S was, however, more with variety HC-136 in 1988 and with HD-2 in 1989 which is associated with higher dry matter production of former and greater nutrient content of the latter one (Table 42 and Fig. 33 & 34).

The concentration of N and S improved with their increasing fertilizer doses in both the years. This, however, gradually narrowed down the N : S ratio as the magnitude of increase was more in the content of S than N. These findings corroborate with those of Singh and Singh (1987) in sorghum and Gaur et al. (1971) in maize. Hazra (1988) reported that these two nutrients are often found to increase the concentration and uptake of each other. Application of S in the absence of N decreased the N concentration in Brassica plants, when N was added with S, the effect was synergistic. Similarly, the maximum forage yield and uptake of nitrogen and sulphur were obtained at 60 kg N + 40 kg S/ha (Tripathi and Hazra, 1988).

Varietal response to applied nutrients and fertilizer use efficiency:

The studies on response functions indicated linear response to nitrogen and sulphur nutrition for all the sorghum varieties (Fig. 35 to 40). This ,therefore ,suggests that within the range of 30 to 90 kg N/ha and 0 to 30 kg S/ha, the short (HD-2), medium (PC-6) and long (HC-136) duration sorghum varieties responded linearly to both nitrogen and sulphur application. In view of linear nature of response functions it was not possible to work out the optimum doses of these plant nutrients. Medina et al. (1984) also observed that nitrogen application upto 150 kg/ha increased the dry matter yields of different sorghum varieties linearly. Gill et al. (1983) found 141.6 kg/ha as the optimum dose of nitrogen for forage sorghum and the response to per kg of fertilizer N was 0.53 q/ha. Forage sorghum has been reported to respond significantly to as high as 280 kg N/ha on sandy soil (Gill et al., 1967). Similarly, there is increasing evidence to suggest that production response to applied S is more likely with forage crops/grassland on light textured soils receiving high rates of fertilizer N (Syers et al., 1988; Klessa et al., 1989).

The responses to per kg of applied nitrogen or sulphur varied from variety to variety and the degree of response decreased with increasing doses of nutrients in all the varieties (Table 45). Though variety HC-136 registered the highest level of response to each kg of

fertilizer nitrogen both in green and dry matter yields but the magnitude of increase remained less than a half at 90 kg N/ha as compared to 30 kg N/ha with all the sorghum varieties. This, therefore, suggests that fertilizer use efficiency decreases with increasing levels of nutrients. The finding is in conformity with those of Byale *et al*. (1987) who found that the grain yield and nitrogen uptake of hybrid sorghum increased by increasing the nitrogen rate from 0 to 160 kg/ha. Nitrogen use efficiency, however, decreased at higher levels of nitrogen fertilization.

The linear nature of response to sulphur from 0 to 30 kg/ha suggests that these sorghum varieties exhibit the characteristics of responding beyond 30 kg S/ha. Similar to nitrogen, the increasing doses of sulphur decreased the magnitude of increase in forage yield to each kg of applied S and the level of response varied with varieties.

S U M M A R Y   A N D   C O N C L U S I O N S

SUMMARY AND CONCLUSIONS

The field investigation entitled "Studies on nitrogen and sulphur nutrition of sorghum varieties for forage yield and quality under rainfed conditions" was conducted at Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (UP) during *kharif* season of 1988 and 1989. The treatments consisting of three sorghum varieties (PC-6, HD-2 and HC-136) each at three levels of nitrogen (30, 60 and 90 kg/ha) and sulphur (0, 15 and 30 kg/ha) were evaluated in 3^3 partial confounding design replicated twice with six blocks each of nine plots. The experimental findings have been summarised in the following sections:

Crop growth, forage yield and quality traits in relation to weather conditions:

The rainfall during crop period was 556.3 mm in 35 rainy days in 1988 and 634.3 mm in 21 rainy days in 1989. Though the total rainfall was higher in 1989 but its distribution was better in 1988. The crop period in 1989 faced two critical dry spells each of two weeks duration from July 23 to August 5 and from September 3 to 16. These coincided with establishment and grand vegetative growth phase respectively. On the other hand, the year 1988 had only one week rainless period from September 3 when crop had already completed the vegetative growth phase. It was in this context that the crop growth and yields were better in 1988 as compared to that in 1989. The favourable weather

conditions in 1988 produced taller plants with greater number of leaves. The length, breadth and area of individual leaf were higher in 1988 than in 1989. The data on relative leaf turgidity and T_c-T_a values indicated that plants maintained higher degree of water status in 1988. All these growth attributes positively contributed to higher green forage (367.4 q/ha) and dry matter(125.0 q/ha) yields in 1988 as compared to 1989 (334.2 q green and 116.6 q dry matter/ha). Moreover, drought year 1989 produced forage with relatively higher dry matter content. As such the green forage productivity was higher in first year (4.33 q/ha/day) but there was not much difference in dry matter productivity per day.

The crude protein content at 25, 55 and 85 days after sowing (DAS) was higher in 1988 whereas at 40, 70 and 100 DAS the values were comparatively more in 1989. The water soluble carbohydrates content, however, remained higher upto 70 DAS in 1988 and thereafter it was more or less similar in both the years. The hydrocyanic acid content remained fairly higher at 25 and 40 DAS in drought year of 1989 and thereafter the differences were levelled off.

Among fibre fractions, plants showed relatively higher contents of ADF, cellulose and lignin in 1989 whereas the reverse was the case with respect to NDF and hemicellulose. However, the differences were marginal. There was not much difference in nitrogen content of forage

in two years, however, sulphur content was more in 1988 as compared to 1989. Consequently the N : S ratio happened to be 7.12 in 1989 against 5.89 in 1988. The uptake of N and S was greater in 1988 than in 1989.

Growth characters and forage yield:

Variety HC-136 excelled others in plant height, number of functional leaves and leaf breadth in both the years and in leaf area in 1988. Variety HD-2, however, produced longer leaves in both the years with greater leaf area in 1989. Leaf : stem ratio on the other hand, was more in PC-6 in both the years. HC-136 maintained higher relative leaf turgidity but HD-2 exhibited lower plant water stress in terms of T_c-T_a values. Variety HC-136 produced significantly higher green forage (443.9 q/ha in 1988 and 371.6 q/ha in 1989) and dry matter (150.9 q/ha in 1988 and 131.8 q/ha in 1989) yields over HD-2 and PC-6. In terms of productivity per day, however, HD-2 producing green forage of 4.75 q/ha/day in 1988 and 4.58 q/ha/day in 1989 proved superior over other varieties. The corresponding dry matter productivity was 1.58 and 1.52 q/ha/day.

Increasing levels of nitrogen increased plant height, number of functional leaves, length, breadth and area of leaf with the result that highest values were obtained with 90 kg N/ha in both the years. Leaf : stem ratio was also wider at 90 kg N/ha in 1989, whereas in 1988 it was at par

with 60 kg N/ha. Plants maintained higher relative turgidity when fertilized with 90 kg N/ha but experienced lower plant water stress (T_c-T_a) at 30 kg N/ha. Application of 90 kg N/ha produced significantly higher green forage (416.8 q/ha in 1988 and 370.2 q/ha in 1989) and dry matter (143.0 q/ha in 1988 and 135.8 q/ha in 1989) yields over 30 and 60 kg N/ha. Likewise the increasing doses of nitrogen from 30 to 90 kg/ha caused an increase in green forage productivity from 3.83 to 4.91 q/ha/day in 1988 and from 3.41 to 4.50 q/ha/day in 1989. The corresponding increases in dry matter productivity were from 1.17 to 1.58 q/ha/day in 1988 and from 1.24 to 1.67 q/ha/day in 1989.

In general, sulphur nutrition exercised favourable effect on growth characters with the result that the application of 30 kg S/ha produced taller plants with more number of longer and broader functional leaves except that number of leaves with with 15 and 30 kg S/ha were almost similar in 1989. There was no definite trend in leaf:stem ratio with respect to sulphur levels. The relative leaf turgidity was more with 30 kg S/ha whereas plants were able to keep the plant water stress (T_c-T_a) lower at 15 kg S/ha. Forage yields increased significantly with 15 and 30 kg S/ha except dry matter yield in 1988 where 15 kg S/ha was at par with control treatment. Similarly the green forage productivity increased from 4.00 to 4.66 q/ha/day in 1988

and from 3.50 to 4.41 q/ha in 1989 with an increase in S levels from 0 to 30 kg/ha. The increase in dry matter productivity was from 1.33 to 1.58 q/ha/day in both the years.

The significant V x N and V x S interactions follow that HC-136 fertilized with 60 kg N/ha produced dry matter equivalent to HD-2 receiving 90 kg N/ha. Similarly, HC-136 at 15 kg S/ha yielded dry matter at par with HD-2 at 30 kg S/ha. The significant N x S interaction indicates that fertilizer schedule of 90 kg N + 15 kg S/ha produced dry matter similar to 60 kg N + 30 kg S/ha. This suggests the possibility of substituting 30 kg N/ha with 15 kg S/ha.

Quality traits:

Crude protein: In 1988 variety HD-2 contained higher crude protein per cent at early stage of growth whereas HC-136 continued to register higher protein content thereafter. In 1989, however, HD-2 excelled other varieties in protein content upto 55 DAS. PC-6 at 70 DAS and HC-136 at 85 DAS gave higher protein content. While comparing the varieties at their respective harvesting stage, HD-2 had an edge over others in protein content in both the years (5.46% in 1988 and 6.44% in 1989).

Nitrogen nutrition exercised distinct effect on protein content and application of 90 kg N/ha recorded higher protein content at all the stages of growth in

both the years. The difference was, however, more pronounced at 55 DAS in 1988 and at 25 DAS in 1989. At harvesting stage 30, 60 and 90 kg N/ha gave crude protein content of 4.83, 5.25 and 5.60 per cent in 1988 and 4.98, 5.27 and 6.12 per cent in 1989 respectively.

Increasing levels of sulphur from 0 to 30 kg/ha increased protein content of forage sorghum at all the stages of growth. At harvesting stage, the difference was more marked between 0 and 15 kg S/ha in 1988 and between 15 and 30 kg S/ha in 1989.

<u>Water soluble carbohydrates</u>: In general, the water soluble carbohydrates increased at advanced stages of crop growth. This kind of trend was maintained particularly in 1989. In 1988, HC-136 showed higher WSC content at all the stages and more so at 70 DAS. In 1989 at this stage, however, HD-2 contained higher WSC as compared to other varieties. Sorghum varieties PC-6, HD-2 and HC-136 had WSC content of 4.39, 7.37 and 8.44 per cent in 1988 and 5.92, 7.21 and 7.26 per cent in 1989, respectively.

Application of nitrogen from 30 to 90 kg/ha increased the WSC content at all the stages of crop growth in both the years. The effect was, however, more marked at 70 and 100 DAS in 1988 and at 40 DAS in 1989. It follows that at harvesting stage 30, 60 and 90 kg N/ha resulted in WSC content of 5.10, 6.53 and 8.57 per cent in 1988 and 6.24, 6.76 and 7.28 per cent in 1989, respectively.

Sulphur nutrition from 0 to 30 kg/ha increased the WSC content at all the stages of growth in both the years. The degree of response was variable in 1988 but consistent in 1989. At harvesting stage 0, 15 and 30 kg S/ha exhibited WSC contents of 6.41, 6.68 and 7.11 per cent in 1988 and 5.54, 6.67 and 8.07 per cent in 1989, respectively.

<u>Hydrocyanic acid</u>: The HCN content declined as the crop advanced in age and the decrease was more sharp from 25 to 40 DAS. Thereafter, the decrease was gradual in both the years. Variety PC-6 contained lower HCN at all the stages of growth except at 55 DAS in 1988 when HC-136 showed lower HCN content. Variety HD-2 on the other hand, registered highest HCN content in both the years and more so at 25 DAS when it exhibited HCN content of 504.3 ppm in 1988 and 615.3 ppm in 1989. The corresponding values at 40 DAS were 235.9 and 290.9 ppm.

Increasing doses of nitrogen from 30 to 90 kg/ha caused an increase in HCN content at all the growth stages in both the years. The effect was, however, more pronounced in drought year at 25 DAS when the concentration increased from 426.1 to 576.5 ppm at corresponding N levels.

In contrast sulphur nutrition caused reduction in HCN content at all the stages of crop growth. The effect of 15 and 30 kg S/ha over control treatment was more distinct at 25 DAS particularly in drought year 1989 when 30 kg S/ha reduced the HCN concentration from 632.8 to 328.7 ppm.

Fibre fractions:

Variety HC-136 had lower contents of NDF, ADF, cellulose and lignin in both the years. The hemicellulose content was observed to be minimum with PC-6 in 1988 and with HD-2 in 1989. Plant silica was comparatively lower in PC-6 as compared to other varieties.

Nitrogen did not exercise any definite trend with respect to fibre fractions. Application of 30 kg N/ha gave relatively lower contents of NDF and hemicellulose in 1988, ADF in 1989 and lignin in both the years. ADF in 1988, NDF and hemicellulose in 1989 were lower with 60 kg N/ha. However, lower contents of cellulose and plant silica were obtained with 90 kg N/ha in both the years.

Sulphur nutrition did not modify the fibre fractions tangibly. Application of 15 kg S/ha, however, resulted in lower ADF content. Lower contents of cellulose, lignin and plant silica were observed at 30 kg S/ha in 1988 but at 15 kg S/ha in 1989. Use of sulphur marginally increased the NDF content in plants.

Nutrient contents, their ratio and uptake:

Nitrogen and sulphur content was more in variety HD-2 except that in 1988, variety HC-136 gave marginally higher S content than HD-2. PC-6 in 1988 and HC-136 closely followed by HD-2 in 1989 gave higher N : S ratio. Variety HC-136 caused greater uptake of N and S in 1988 whereas HD-2 did so in 1989.

Nitrogen at 90 kg/ha resulted in the highest N and S contents, but narrowed down the N:S ratio. The uptake of these nutrients was also maximum at 90 kg N/ha. Similarly, sulphur nutrition increased the contents of N and S, narrowed down their ratio and enhanced the uptake in both the years.

<u>Varietal response to fertilizer nitrogen and sulphur</u>:

All the sorghum varieties exhibited linear response to applied nitrogen and sulphur both in terms of green forage production and dry matter accumulation. Short (HD-2), medium (PC-6) and long (HC-136) duration varieties possessed the characteristics of responding beyond 90 kg N and 30 kg S/ha.

The magnitude of response to each kg of applied nitrogen decreased with increasing doses and the degree of response remained less than half at 90 kg N/ha as compared to 30 kg N/ha with all the sorghum varieties. Variety HC-136, however, registered the highest response to each kg of fertilizer nitrogen at all the levels.

Similarly increasing doses of sulphur decreased the magnitude of response to each kg of applied sulphur and the level of response varied from variety to variety.

From the results summarised above, the following conclusions may be drawn:

1. Sorghum variety HC-136 proved superior in growth attributes, forage yield potential and WSC content while HD-2 showed its prominance for drought tolerance, protein content and productivity per day. Variety PC-6, however, accumulated lowest HCN content.
2. All the three sorghum varieties responded linearly to applied fertilizer nitrogen ranging from 30 to 90 kg/ha and sulphur from 0 to 30 kg/ha in terms of green forage yield and dry matter producton.
3. Nitrogen and sulphur nutrition had a distinct positive effect on crude protein and WSC contents at different stages of crop growth.
4. Accumulation of HCN in plants increased with N but decreased with S application under dryland environment experiencing periodic soil moisture stress.
5. Therefore, under rainfed conditions, sorghum variety HC-136 may be fertilized with 90 kg N + 30 kg S/ha for achieving higher forage yield, better quality traits and greater nutrient outturn.

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